PB-216 194

WATER QUALITY CONSERVATION ARKANSAS-RED RIVER BASINS. SUMMARY REPORT ON A BASIC STUDY OF WATER QUALITY, SOURCES OF NATURAL AND MANMADE SALT POLLUTION, AND SUGGESTED CORRECTIVE MEASURES

Public Health Service
Dallas, Texas

March 1964

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WATER QUALITY CONSERVATION ARKANSAS-RED RIVER BASINS

Summary Report on a Basic Study of Water Quality, Sources of Natural and Manmade Salt Pollution, and Suggested Corrective Measures

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas
MARCH 1964

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WATER QUALITY CONSERVATION

ARKANSAS-RED RIVER BASINS

Summary Report on a Basic Study of Water Quality,
Sources of Natural and Manmade Salt Pollution,
and Suggested Corrective Measures

Details of illustrations in
this document may be better
studied on microfiche.

By

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Division of Water Supply and Pollution Control
Dallas, Texas

JANUARY 1964

PREFACE

The Arkansas and Red Rivers and their tributaries are one of the Nation's largest water resources and drain about 8 percent of the continental United States. These river basins encompass all of Oklahoma and parts of Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas, and Louisiana.

The high mineral content of the Arkansas and Red Rivers and of some of their tributaries limits their use as sources of water supply for municipalities, industries, and agriculture. The mineral pollution of these streams results principally from both natural brine emissions and oil production activities.

The Arkansas-Red River basins study, concentrating on abatement of natural and manmade brines, begun in 1958, represents the first step in the development of a comprehensive program to control water pollution. Preliminary evaluations of the available data and general scope of the problem were made in cooperation with numerous Federal, State, and local agencies. As a result, detailed basin-wide studies were recommended to provide the basic information required to more fully define the problem and develop plans for quality improvement in these two great river basins.

In August 1959, Congress provided for the continuation of the study by approving funds for ". . . the Arkansas-Red River water quality conservation project." 1/ Field investigations were conducted for two years to provide information for a basic report. Natural and manmade sources of salt pollution needed to be identified and described and proposals made for the reduction or elimination of natural salt discharges into the Arkansas-Red River system.

This report presents the major findings, conclusions, and recommendations of the study. Detailed discussions and supporting data are presented in a separate appendix comprising three volumes:

Volume I The Mineral Pollution Problem and Proposed Solutions
Volume II Water Quality Data
Volume III Benefit Evaluation

The Senate Committee on Public Works, by resolution adopted December 16, 1959, requested the Board of Engineers for Rivers and Harbors to review former reports of the Chief of Engineers on the Arkansas and Red Rivers and their tributaries. The Committee requested that this be done with a view to determining, in cooperation with the Division of Water Supply and Pollution Control, Public Health Service, methods and means of improving and managing water quality in these basins. A report by the U.S. Army (Corps of Engineers) is scheduled for release in two parts, the first part in March 1964.

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I. INTRODUCTION

Authority for Project

Investigations of salt pollution of the Arkansas and Red Rivers were undertaken by the Public Health Service as authorized by the Federal Water Pollution Control Act (33 USC 466 et seq.).

Purpose and Scope of Project

The objectives of the project were:

1. To locate and define the significant natural and manmade sources of salt (mineral) pollution.

2. To determine the effects of these sources on the quality of water in the receiving streams.

3. To propose possible methods and procedures for reduction of these highly mineralized discharges.

4. To estimate the results of reduction of these discharges on stream quality.

5. To determine the benefits of water quality improvements to present and future municipal, industrial, and agricultural water users.

Intensive study and investigation of mineral pollution and its causes, both natural and manmade, were carried out on the Arkansas and Red Rivers together with their tributaries in the middle third of the basins. This study covered all of water years 1961 and 1962.

The investigation of benefits considered the impact of water quality improvement on municipal, industrial, and agricultural water uses. The evaluation was extended to include areas immediately adjacent to, and forming an integral part of economy of, the Arkansas-Red River basins. The evaluation extended through the year 2070, with emphasis on the 1970-2020 period.

Acknowledgments

Cooperation and services provided by representatives of many Federal, State, and local agencies, and from industries are gratefully acknowledged. Among those providing such assistance were:

Federal Power Commission
Corps of Engineers

U.S. Department of Agriculture
U.S. Department of Commerce
U.S. Department of the Interior
U.S. Department of Labor
Arkansas-White-Red River Basins Inter-Agency Committee

Kansas - (1) State Board of Health, (2) Water Resources Board, (3) State Highway Department, (4) Local (County and District) Departments of Health, and (5) Corporation Commission.

Oklahoma - (1) State Department of Health, (2) State Highway Department, (3) Corporation Commission, (4) Water Resources Board, (5) Local Health Departments, and (6) University of Oklahoma.

Texas - (1) State Department of Health, Water Pollution Commission, (2) State Highway Department, (3) Railroad Commission, (4) Texas Water Commission, (5) Red River Authority (Pollution Control Program), and (6) Local Health Departments.

Arkansas - (1) State Department of Health, (2) Water Pollution Commission, (3) State Highway Department, and (4) Local Health Departments.

Appreciation is also expressed to the following members of an advisory technical review committee who, before and during the intensive portions of the study, gave so willingly of their time and talent:

Dwight F. Metzler, Executive Secretary, State Water Resources Board, Kansas, 1957-1963

Richard S. Green, Chief, Basic Data Branch, Washington, D. C., 1957-1963

Burdge Irelan, District Chemist, U.S. Geological Survey, Quality Water Branch, Austin, Texas, 1957-1961

A. A. Fischback, Jr., District Engineer, U.S. Geological Survey, Surface Water Branch, Oklahoma, 1961-1963

Maurice LeBosquet, Jr., Special Assistant to Chief, Division of Water Supply and Pollution Control, Washington, D. C., 1957-1958

W. W. Towne, Project Director, Columbia River Basin Project, Portland, Oregon, 1958-1961

Frank DeMartini, Chief, Field Operations Section, Robert A. Taft Sanitary Engineering Center, 1961-1963

II. SUMMARY OF FINDINGS

1. Salt (sodium chloride) and, to a lesser extent, gypsum (calcium sulfate) are the principal mineral pollutants of large volumes of surface waters and some ground waters in the Arkansas-Red River basins. This pollution enters waters of the basins principally as brine from both natural and manmade sources. It is estimated that emissions and releases from these sources, contributing 95 percent of the concentrated brine pollution, represent considerably less than 1 percent of average total streamflow in the basins.

2. The natural brines, ranging in chloride concentration from 20,000 to 190,000 milligrams per liter (mg/l), come from individual large springs, numerous small seeps, large marshes, or salt encrusted flats. Fifteen significant sources of natural mineral pollution, five in the Arkansas River basin and ten in the Red River basin, have been located and identified as the primary causes of water quality deterioration with respect to minerals. Nine additional natural salt sources have been located, three in the Arkansas River basin and six in the Red River basin, and classified as of secondary importance.

3. A Geological Survey report on a study carried out for the Public Health Service indicates that, for each natural source of pollution, the fresh water recharge areas and the brine emission points are relatively close to each other, probably within 10 miles.

4. Brines entering the basins' waters resulting from man's activities are largely the consequence of petroleum and natural gas production.

5. Indications from the State water pollution control agencies of Kansas, Oklahoma, and Texas, are that over 95 percent of the brines produced as a result of petroleum and natural gas extraction activities within the Arkansas-Red River basins is reinjected into the producing strata for secondary petroleum recovery and/or pollution abatement.

6. Some streams, such as the Cimarron River in Oklahoma and the Wichita River in Texas, are polluted primarily by natural brines; while other streams, mainly those of the Canadian River system outside the natural brine producing areas, appear to be polluted only by man-made wastes.

7. During the 2 years (1961-1962) of intensive study, an average of 27,000 tons per day of salt (as NaCl) was detected in the Arkansas-Red River basins upstream from Van Buren, Arkansas, (near Fort Smith on the Arkansas River) and Index, Arkansas, (near Texarkana on the Red River). It has been determined that 14,000 tons per day (NaCl) or 53 percent were from primary and secondary sources of natural brine pollution, while the remaining 13,000 tons per day were from other sources, manmade and minor natural.

8. As a result of brine emissions and releases, water quality is seriously degraded so as to be unsuitable for general municipal, industrial, and agricultural use in various tributaries and the main stems of the Arkansas and Red Rivers. According to the drinking water standards adopted by the States and the Public Health Service, the presence in drinking water of either chlorides (as Cl*) or sulfates (as SO4*) in excess of 250 mg/l is unacceptable, if other more suitable supplies are or can be made available. At average flows, more than 9 million acre-feet of the annual discharges of the Arkansas and the Red Rivers contain chloride concentrations exceeding 250 mg/l. This water quality impairment extends over more than 1,000 stream miles in the middle third of each basin.

9. In addition to chlorides, surface and ground waters of these basins are polluted by sulfates originating in widespread gypsum deposits. The total sulfate loading in the area amounts to about 9,600 tons per day. The principal salt sources account for only 500 tons of sulfate.

---

* Unless otherwise stated, in this report "chlorides" and "sulfates" refer to Cl^- and $SO_4^=$ respectively.

10. The following general methods for control of pollution from the natural brine sources have been suggested to the Corps of Engineers:

    a. Subsurface disposal of concentrated brines.

    b. Permanent storage-retention of concentrated brines in source areas.

    c. Elimination of fresh recharge water to the brine generation areas.

    d. Imposition of back pressure on brine springs to suppress flow.

    e. Transportation of concentrated brines, or solid salt, to nondamaging site (i.e., remote disposal site or Gulf of Mexico).

    f. Utilization of salt.

    The Corps of Engineers has undertaken preliminary studies of the works required to eliminate or reduce natural mineral pollution. Two field tests of control, by increasing the hydrostatic head on natural springs, were started in 1963. These tests are continuing at Estelline Spring, Texas, on Prairie Dog Town Fork of the Red River and near Guthrie, Texas, on the South Fork, Wichita River, Texas, a tributary of Red River.

11. Reduction of mineral pollution by control of the significant natural pollution sources located and defined by this study together with adequate control of manmade sources of mineral pollution will result in water of quality suitable for general municipal, industrial, and agricultural use through nearly all of the basins.

12. Reduction of chloride concentration to 100 mg/l is considered a desirable goal. Availability of water of this quality will encourage maximum water use and development in the basins.

13. If the water quality of the two-river systems is improved sufficiently to meet future water requirements, the average annual value of the benefits, over the 50-year period between 1970 and 2020, will be $9,177,000. This value of the benefits, when spread over the 100-year period between 1970 and 2070, will amount to $13,080,000 annually.

III. RECOMMENDATIONS

The findings of the Arkansas-Red River Basins Water Quality Conservation Project have provided a basis for considering control of salt pollution in the two rivers. In accordance with these findings, the following 4-point program is recommended for approval and implementation as rapidly as legislative authority and appropriation permit.

1. As soon as the U.S. Army Engineers designs and costs are available, engineering works should be considered for construction to control natural salt emission at the 15 major sources identified in this report. First priority should be given to three tributaries of the Wichita River, Elm Fork of the Red River, Estelline Spring, and Jonah Creek in Texas, and the Big and Little Salt Plains on the Cimarron River together with the Great Salt Plains on the Salt Fork of the Arkansas River in Oklahoma.

2. The State and the Federal governments should continue and strengthen their efforts to reduce salt pollution arising from oil fields and other mining and industrial operations, using when appropriate and necessary the enforcement provisions of the Federal Water Pollution Control Act.

3. The Public Health Service should immediately institute a continuous and, where possible, automatic system of water pollution monitoring in the two river basins. Such a system would provide intelligence on water quality in the streams, essential to the efficient operation of those structures which are or may be built in the two basins for quality control. Headquarters for the monitoring and data interpretation would be located at the new regional water pollution control laboratory being built at Ada, Oklahoma.

4. The basin States and the Federal government should develop a permanent program of mutually acceptable procedures to minimize the adverse effects of salt pollution at points of water use in the two river basins.

IV. DESCRIPTION OF BASINS

Topography

The Arkansas and Red River basins are located in the southwestern and central plains regions and encompass approximately 8 percent of the land area of the United States, containing all or a portion of the eight States of Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana. (See Figure IV-1.) The combined basins drain a crescent-shaped area of about 254,000 square miles through terrain varying from high rugged mountains over 10,000 feet in elevation in Colorado to coastal and alluvial plains near sea level in Arkansas and Louisiana. 2/

The Arkansas River rises in the Southern Rocky Mountains of Colorado and New Mexico at elevations upwards of 10,000 feet; drops rapidly to the nearly unbroken surface of the high plains at an elevation of about 5,000 feet along the eastern borders of these two States; and then continues southeasterly at more gradual slopes through the high plains, the Ozark-Ouachita uplift, and the Coastal Plain to its confluence with the Mississippi River at an elevation less than 200 feet.

The Red River has its headwaters in the high plains along the western edge of the Texas Panhandle at an elevation of about 4,500 feet. It follows an easterly course forming the border of Oklahoma and Texas and then flows into Arkansas, turns and meanders in a southerly direction through Louisiana where it discharges into the Mississippi River Delta at an elevation less than 100 feet.

The general appearance of both basins is one of smooth plains with distinct escarpments facing the northwest and growing in predominance toward the headwaters. The rivers, beginning in Colorado, originate as swift-flowing mountain streams with rocky bottoms. As they flow into the high plains region, the rivers become broad, shallow, and generally choked with sand. In the Ozark-Ouachita uplift area, the streams are once again fairly swift and clear, only to become sluggish and meandering upon reaching the Coastal Plain.

Hydrology

Average annual precipitation varies from about 55 inches near the mouth of the Red River to 50 inches at the mouth of the Arkansas River. Moving westward, the isohyets are generally oriented north to south and fairly evenly spaced to a low of about 12 inches along the western edge of the Great Plains. Continuing westward, rainfall increases with elevation, reaching a peak of some 32 inches on the eastern slopes of the Rocky Mountain chain in Colorado and New Mexico.

Because of the differences in geography within the Arkansas-Red River basins, the seasonal distribution of precipitation varies widely. In the Coastal Plain, the seasonal distribution is quite uniform, while in the Great Plains and Rocky Mountain regions rainfall reaches a peak in the summer due to convective or thundershower type activity.

In much of the Arkansas-Red River basins, ground waters have supplied essential needs. The bulk of the basins lies in five ground water provinces. 3/

The westernmost portion of the Arkansas River basin lies in the Southern Rocky Mountain province which is underlain for the most part by crystalline rocks. Water is obtained chiefly from springs or spring fed streams, or very shallow wells near the streams.

Moving eastward, part of the Arkansas River basin in eastern Colorado and Kansas is in the Great Plains province. The principal aquifers of this area are the geologically Recent sands and gravels (Ogallala) and the Dakota sandstone, both of which yield large quantities of good quality water. The Ogallala is shallow, while the Dakota sandstone may be too deep for a practical source of water supply in parts of the area. Many valleys also contain gravels of Recent geologic age which supply large quantities of good water.

South of the above province and underlying the Texas and Oklahoma Panhandles and reaching up into Kansas is an earlier Great Plains province. The principal aquifers here are the Recent sands and gravels which give the same favorable ground water conditions as those in the province above. The earliest of these deposits are, however, underlain by red beds which yield little or only highly mineralized water. The ground water conditions are generally unfavorable.

The middle portions of the basins extending into northwestern Arkansas are in the Southcentral province, where ground water conditions are, in general, rather unsatisfactory. The principal sources of supply are the early sandstones and limestones, containing waters which are for the most part meager or of poor quality. Deep water is highly mineralized. Large supplies are obtained from glacial outwash and other alluvial sands and gravels in many of the valleys.

The remainder of the basins lies in the Atlantic Coastal Plain province, where water is obtained in rather large quantities from Recent strata, chiefly sand and gravel interbedded with clay. The alluvium of the Mississippi Valley provides large supplies of good quality water.

Streamflow in these basins is highly variable. In western Oklahoma and Texas, most of the tributary streams are intermittent, while in the lower basins more evenly distributed streamflow is evident. The highest coefficients of variation of streamflow occur between the Colorado-New Mexico border and the eastern border of Oklahoma. These range from 50 percent at both the eastern and western limits to a high of 72 percent in the Neosho River near Parsons, Kansas.[4] The average annual runoff varies from a low of 0.25 inch in the western part of the Great Plains to a high of 20 inches in parts of Arkansas and Louisiana. [5]

Definition of Study Area

The study area as shown in Figure IV-1 encompasses all of the Arkansas and Red River basins plus minor adjoining portions of the Missouri, White, Trinity, Brazos, and Sabine River basins. This area consists of a total of 327 counties in Oklahoma, Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas, and Louisiana, and represents approximately 9 percent of the land area and 5 percent of the population of continental United States.

The study area includes all counties partly or entirely within the Arkansas-Red River basins together with those adjoining counties which are expected to be directly affected by an improvement in the water quality of the mineral polluted streams.

The water quality monitoring studies cover about 60 percent of the area of the Arkansas-Red River basins ranging, on the Arkansas River, from Great Bend, Kansas, to Van Buren, Arkansas, and, on the Red River, from Brice, Texas, to Index, Arkansas (near Texarkana, Texas). These limits were established because they include practically all of the poor quality water and all of the known primary natural salt sources. The major portion of oil-gas brine pollution also occurs within this area.

Economy

The economy of the Arkansas-Red River basins study area is diversified. In land area it covers 302,000 square miles, most of it unpopulated and relatively barren. On the other hand, over 9,300,000 people reside in the area, largely in metropolitan areas varying in size from Dallas with a 1960 population of over a million to cities such as Oklahoma City, Tulsa, and Forth Worth with 1960 populations of about one-half million and Lawton, Oklahoma; Fort Smith, Arkansas; and Texarkana, Texas and Arkansas, with 1960 populations of less than 100,000. [6] The population growth rate of the entire area from 1950 to 1960 has been 1 percent compounded annually. The national rate was 1.75 percent over the same period.

The population trend in the study area reflects the national condition of rural area decline and urban area increase. This change is due to reduction of farm employment opportunities resulting from development of mechanized, large-scale agriculture and to the consequent exodus of the surplus farm labor to the cities, as well as to other migration and social factors.

The study area lost 15 percent of its rural population from 1950 to 1960; the totals were 4,320,000 in 1950 and 3,670,000 in 1960. The urban population grew by 37 percent over the same 10-year period, from 4,120,000 to 5,660,000. 6/ The national rates for these two segments of the population were increases of one-third of 1 percent and 30 percent, respectively, for the same period of time.

These comparisons of national with Arkansas-Red River basins study area population trends indicate that the study area compares favorably with the Nation in growth. This favorable comparison is particularly manifest in the large metropolitan areas (SMSA's*) of the region such as Dallas, Fort Worth, Oklahoma City, Tulsa, Wichita, and Shreveport, which had a population growth rate of 3.25 percent compounded annually from 1950 to 1960. The national rate in these population categories was 2.625 percent. A detailed picture of the SMSA populations in the study area is presented in Table IV-1 and Figure IV-2.

Table IV-1

Study Area Population--Total, Urban, Rural, and Standard Metropolitan Statistical Area 1910-1960 (Millions)

Population Component	1910	1920	1930	1940	1950	1960
Total	6.1	7.1	8.0	8.1	8.4	9.3
Urban	1.3	1.9	2.7	3.0	4.1	5.6
Rural	4.8	5.2	5.3	5.1	4.3	3.7
SMSA**	0.6	1.2	1.8	2.1	3.1	4.3

**SMSA populations for all decades adjusted to include geographic area defined as SMSA in 1960.

Source: Bureau of the Census 7/

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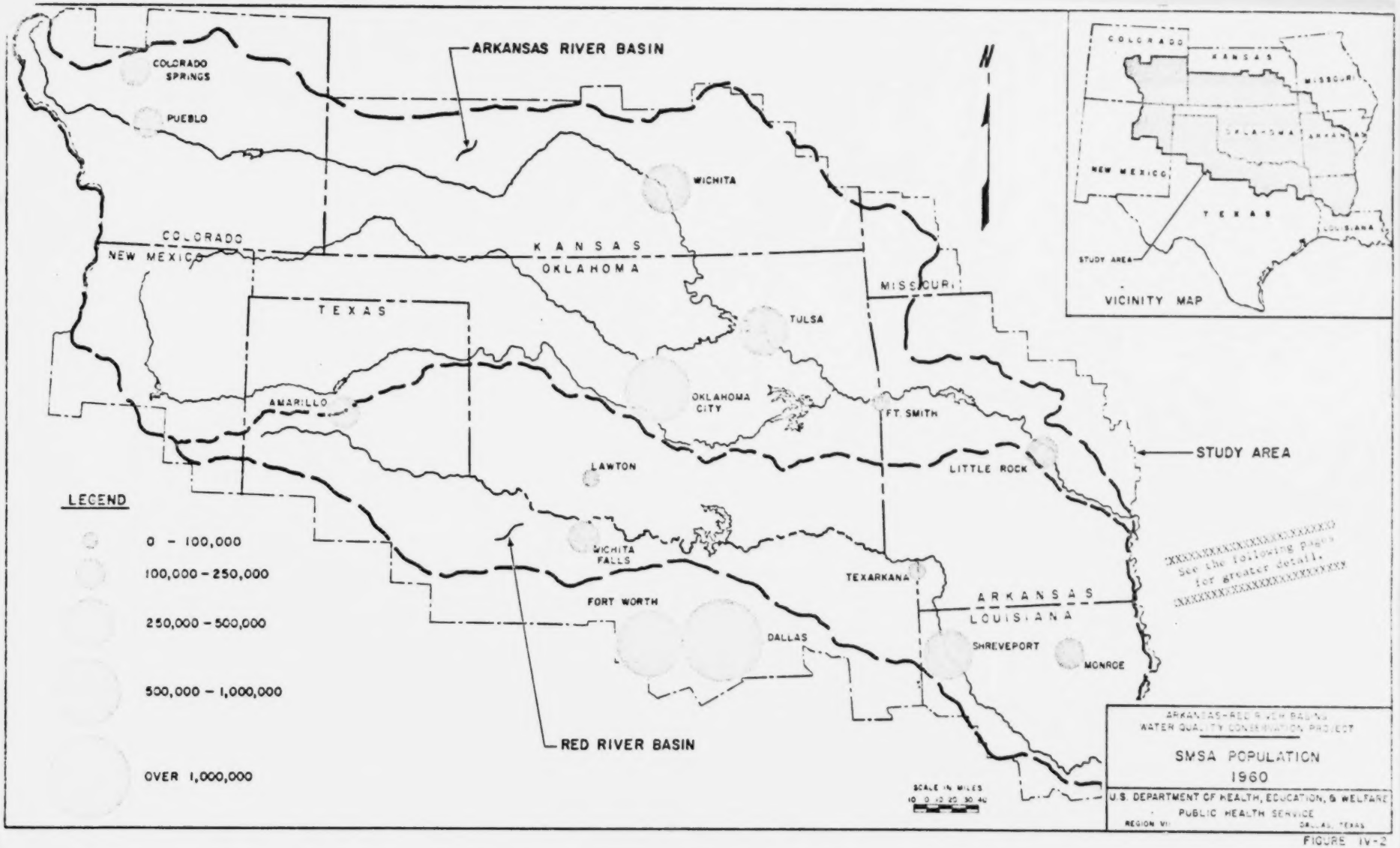
* Standard Metropolitan Statistical Area--A central city with a population of 50,000 or more and its urbanized fringe area.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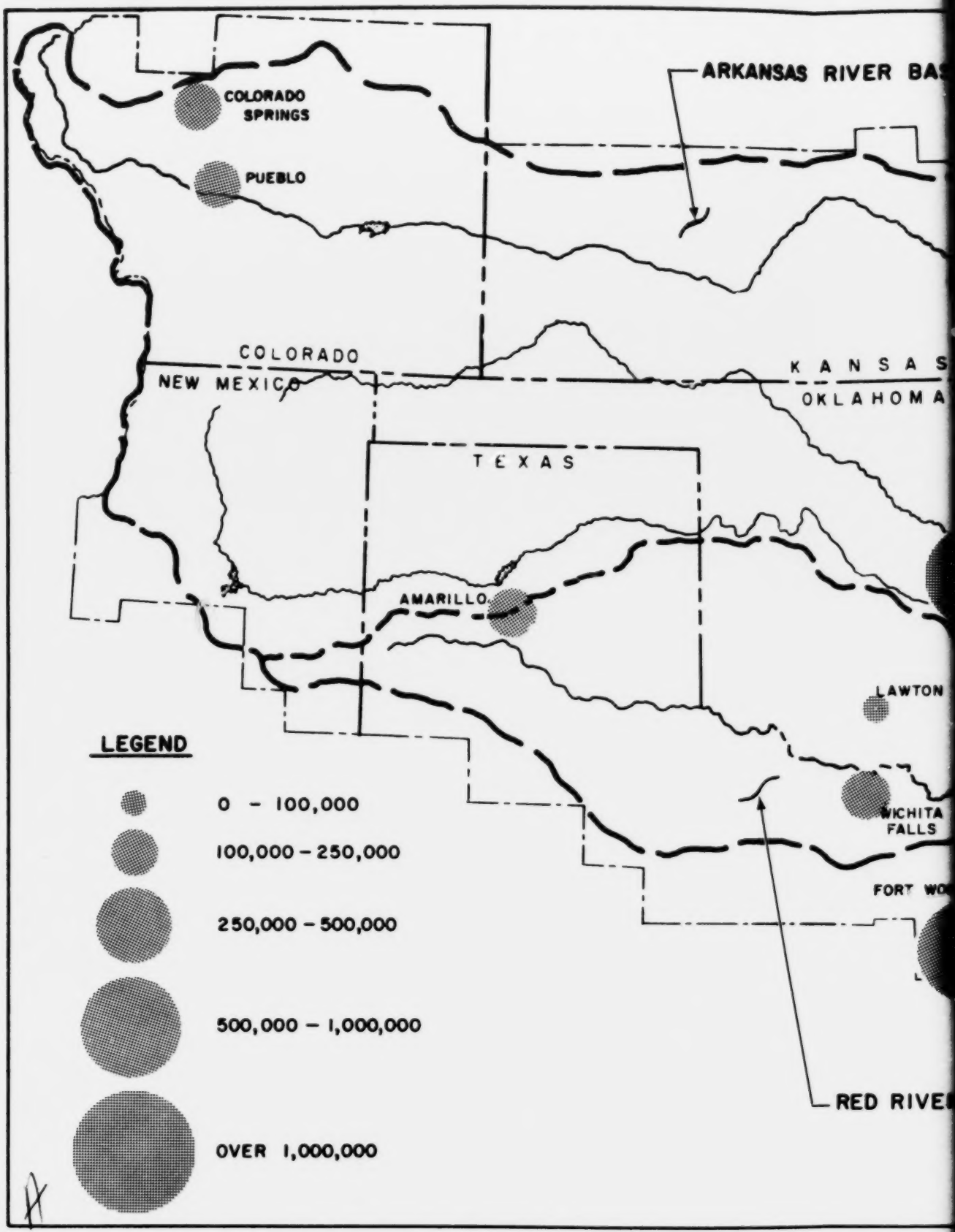
AMARILLO
OKLAHOMA CITY
FT. SMITH
STUDY AREA
LAWTON
LITTLE ROCK
LEGEND
0 - 100,000
100,000 - 250,000
250,000 - 500,000
500,000 - 1,000,000
OVER 1,000,000
WICHITA FALLS
TEXARKANA
ARKANSAS
LOUISIANA
FORT WORTH
DALLAS
SHREVEPORT
MONROE
RED RIVER BASIN
SCALE IN MILES
VICINITY MAP
STUDY AREA
See the following page for greater detail.
ARKANSAS-RED RIVER BASINS WATER QUALITY CONSERVATION PROJECT
SMSA POPULATION
1960
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
DALLAS, TEXAS

FIGURE IV-2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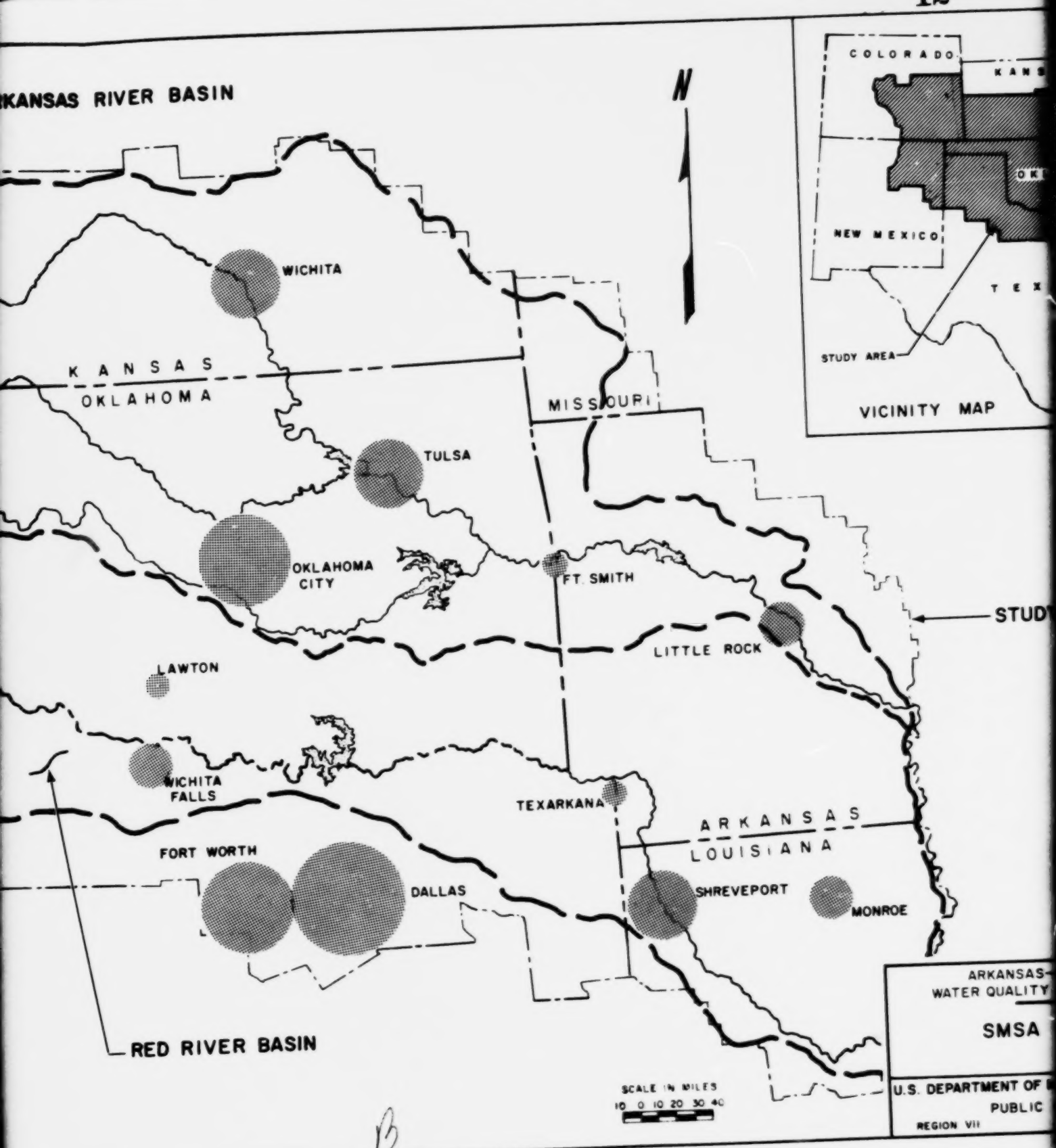
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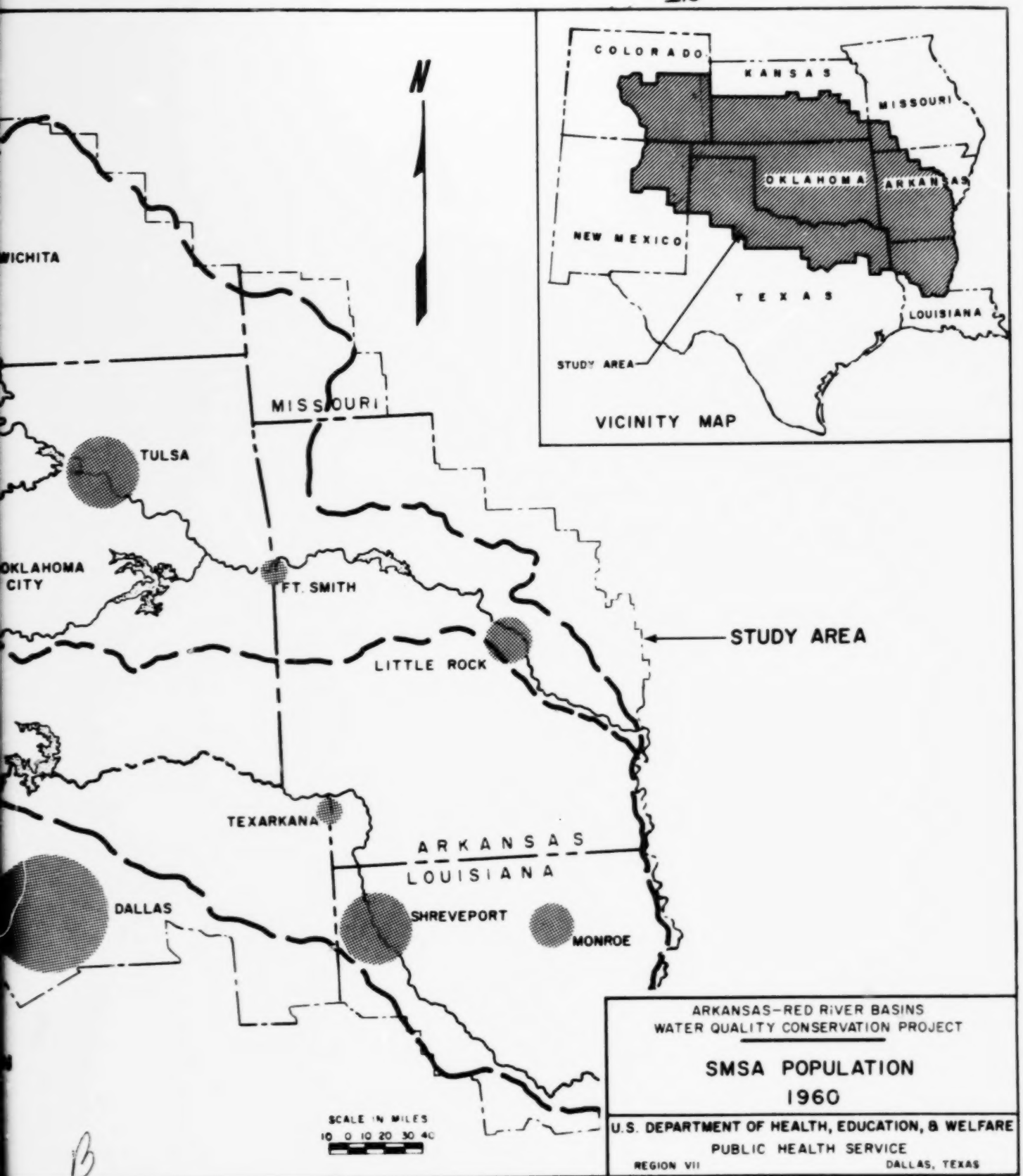


ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

SMSA POPULATION
1960

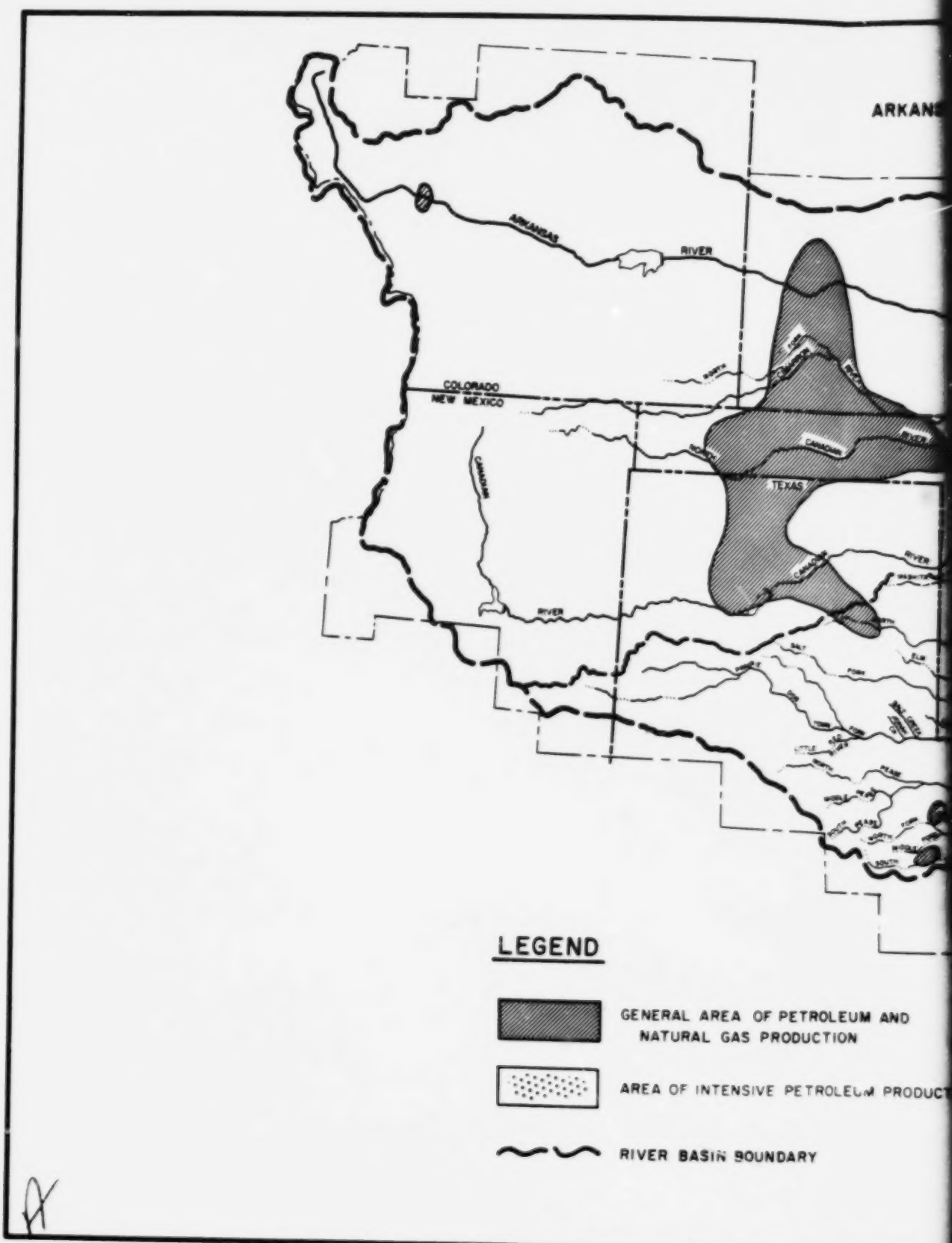
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

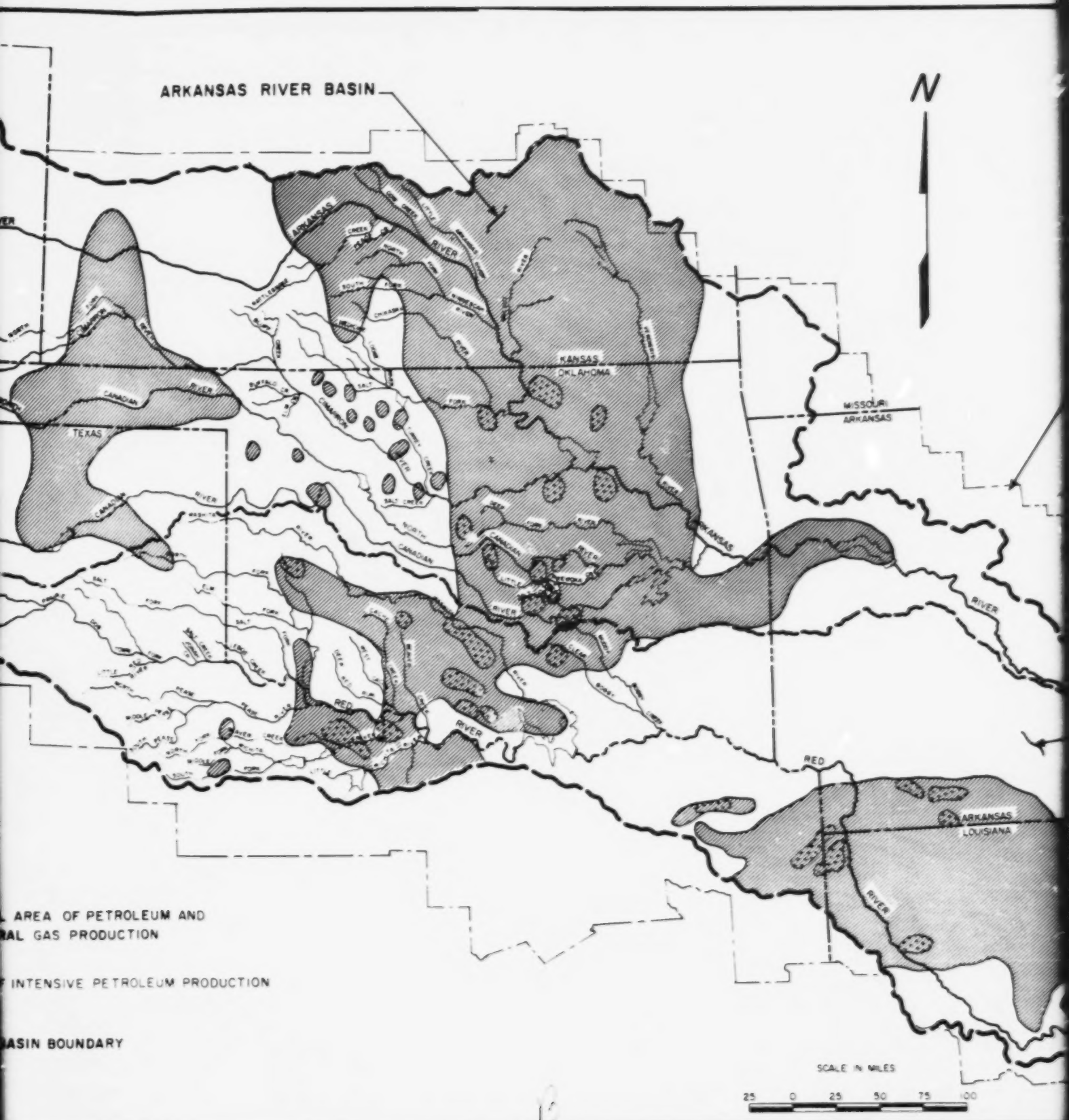
FIGURE IV-2

The diversity of the study area's economy is also indicated by the distribution of the labor force among the several major sectors of employment. For instance, in 1960, 9 percent of a total labor force of 3,370,000 was employed in agriculture; 3 percent was employed in mining, chiefly petroleum and gas drilling; and 17 percent was employed in manufacturing. 8/ Based on the 1950 and 1960 trend, the significant changes in the labor force have been in the agriculture and manufacturing categories. The similarity to the national condition is again manifest in these figures.

The geographic distribution of the labor force is virtually self-evident. The largest percentage is highly urban, particularly metropolitan urban. Since the growth industries are urban metropolitan in their location, it can be seen that the major share of future population growth is likely to occur within the present metropolitan areas. These are the areas that can provide the technical, personal, and business services. Large-scale manufacturing is especially dependent on these services, as well as on the transportation facilities, markets, and labor force accumulations of large metropolitan and urban areas. On the other hand, manufacturing activities less dependent on labor and area markets, chiefly those activities based directly on raw materials such as timber and agricultural crops, often locate in small communities or in rural areas apart from the large population centers. These activities influence the "scatter" of population--its number of centers and the density pattern.

The most conspicuous single feature of the economy of the basin is the prominence of petroleum and natural gas extraction in the creation of wealth and employment. The study area ranks high on the national scale in both volume of production and sales value. In 1960, oil production reached 0.6 billion barrels and gas production reached 3.5 trillion cubic feet. The sales values were $1.7 billion and $½ billion, respectively. This extraction of petroleum and natural gas accounted for approximately one-fourth of the national production. 9/ Figure IV-3 reveals the general location of oil and gas extraction in the study area. 10/


ARKANSAS
RIVER
COLORADO
NEW MEXICO
CANADIAN
TEXAS
LEGEND
GENERAL AREA OF PETROLEUM AND NATURAL GAS PRODUCTION
AREA OF INTENSIVE PETROLEUM PRODUCT
RIVER BASIN BOUNDARY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MISSOURI
ARKANSAS
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LOUISIANA
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RIVER
AREA OF PETROLEUM AND
RAL GAS PRODUCTION
INTENSIVE PETROLEUM PRODUCTION
ASIN BOUNDARY
SCALE IN MILES
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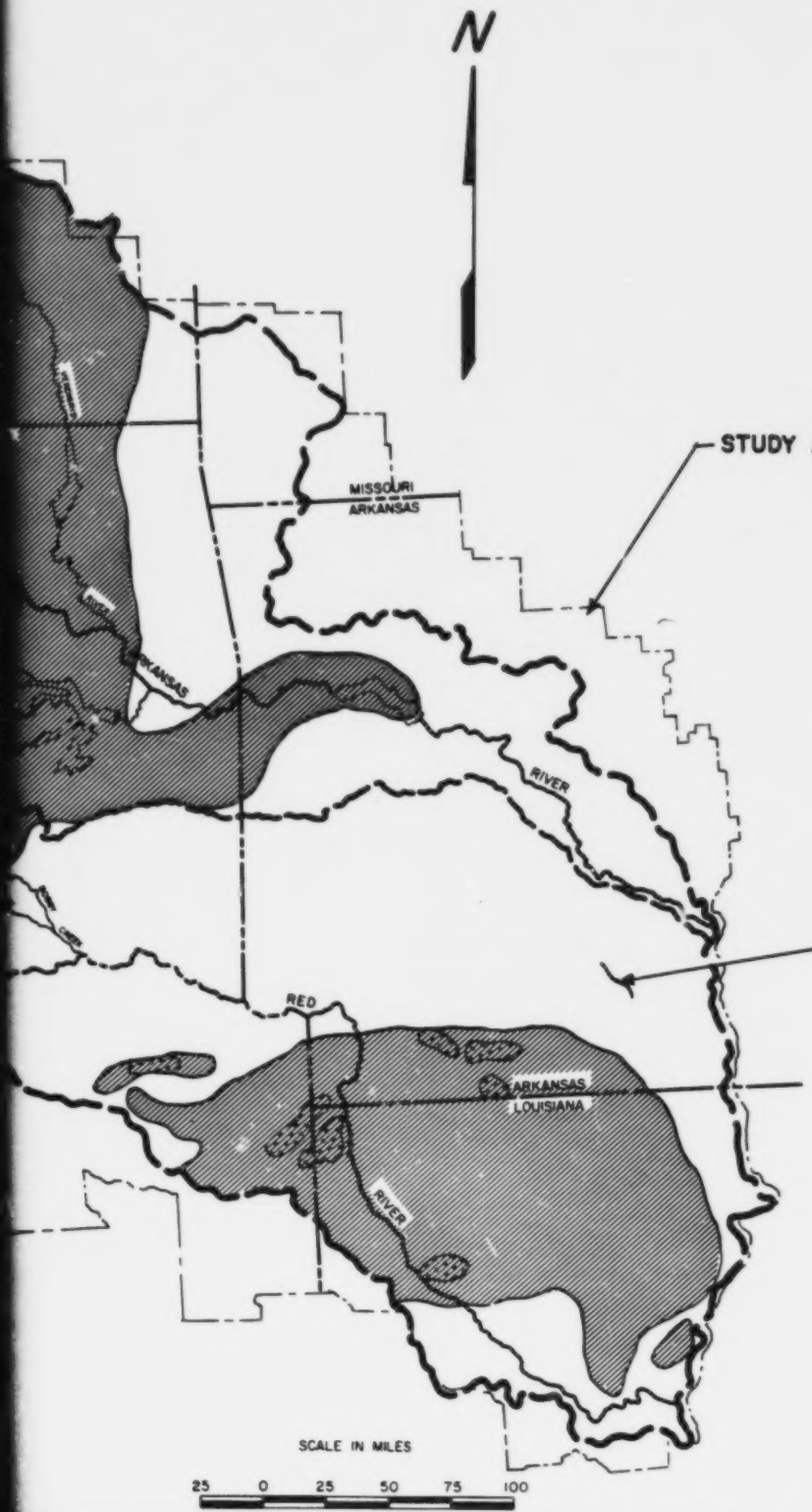


ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

AREAS OF PETROLEUM AND NATURAL GAS PRODUCTION

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE IV–3

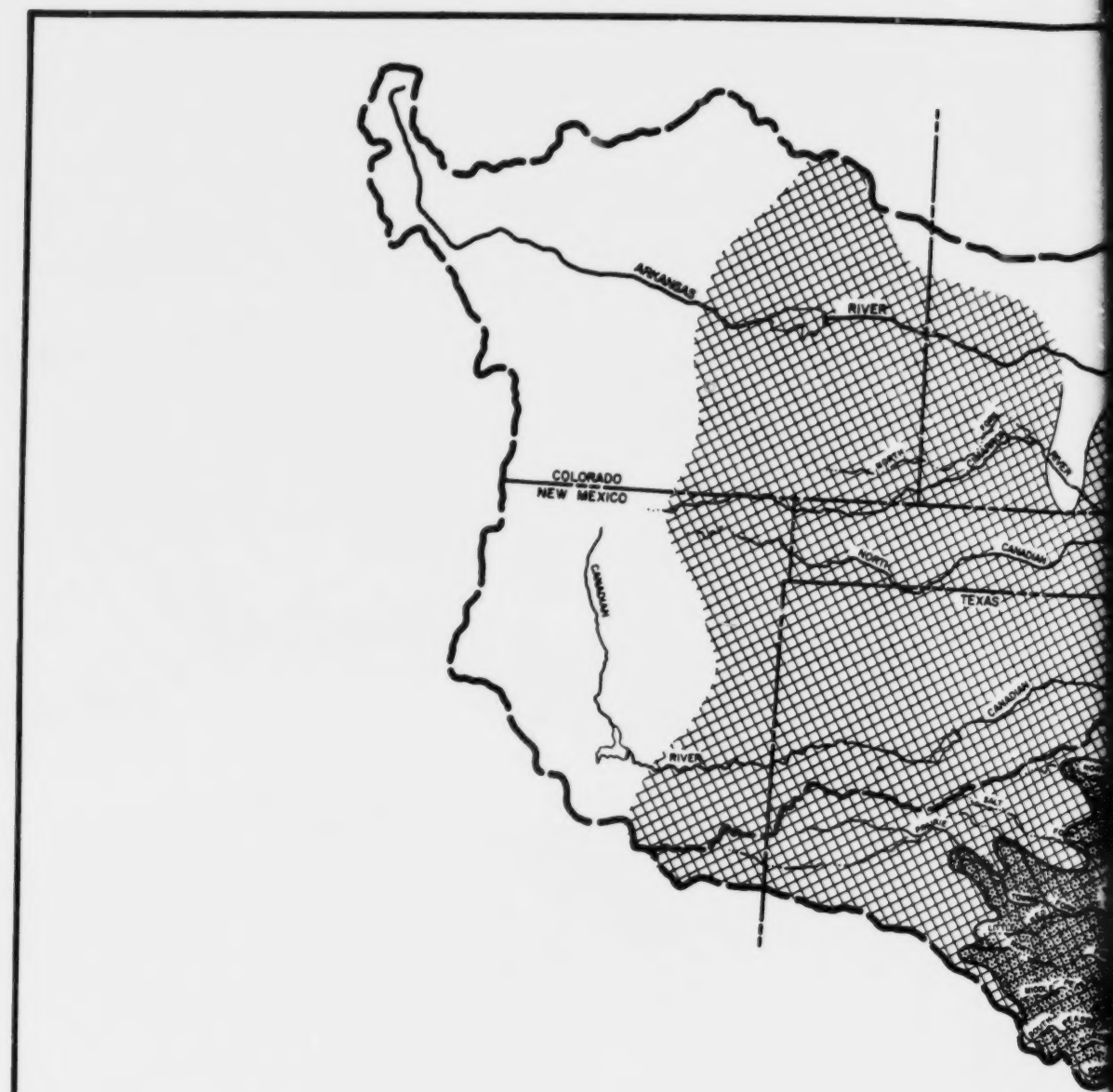
V. DESCRIPTION OF PROBLEM

The principal mineral pollutants in the Arkansas-Red River basins waters are salts--sodium chloride and calcium sulfate. 11/ The 1955 report of the Arkansas-White-Red River Basins Interagency Committee refers to the significance of salt pollution. 12/ As shown in Figure V-1, natural deposits of both minerals are widely distributed. Some salt pollution also results from oil-gas production in the basins, but effective State water pollution control programs are expected to continue to reduce this pollution entering both surface and ground waters.

With ever-increasing water demands, municipalities such as Dallas, Fort Worth, Oklahoma City, Wichita Falls, and Tulsa are reaching considerable distances for good quality water. Oklahoma City, for example, has reached some 100 miles to the southeast of the city for additional water of adequate quality to meet rising needs. The Canadian River, which is located about 20 miles away, is unsuitable for municipal use due to its excessive mineral content.

Even so, it has been necessary for some municipalities to use highly mineralized waters. During the drought of the 1950's, the water supply of Dallas became depleted and the city was forced to take a large portion of its water from the Red River. During a period extending from August 1953 to April 1957, 34,600 million gallons or 110,000 acre-feet of water from Red River with undesirable chloride concentrations were used by the Dallas Water Supply system. 13/ Based upon water quality records at a Geological Survey station located 1½ miles, more or less, downstream from the city's provisional Red River pump station, chloride concentrations ranged from 200 mg/l to 2,000 mg/l during this time. 14/ It is estimated that the salt (NaCl) load in the Dallas system from this source amounted to about 150,000 tons during this period of emergency use. Considerable damage, caused by the high salt concentration, was reported by water department officials. Insurance adjustments and income tax deductions were claimed because of hot water tank corrosions, as well as other damage to plumbing, shrubbery, and vegetation. Many users, by necessity or choice, obtained water of more acceptable quality from outside sources.

The full development and use of all the streams of satisfactory quality which are located reasonably close to the population centers are foreseeable in many parts of the basins. Future needs, rapidly becoming apparent, may well need to be supplied by waters presently carrying objectionable loads of chlorides and sulfates. Furthermore, unanticipated growth in a particular area and/or another severe drought may at any time require emergency use of salt polluted streams.


ARKANSAS
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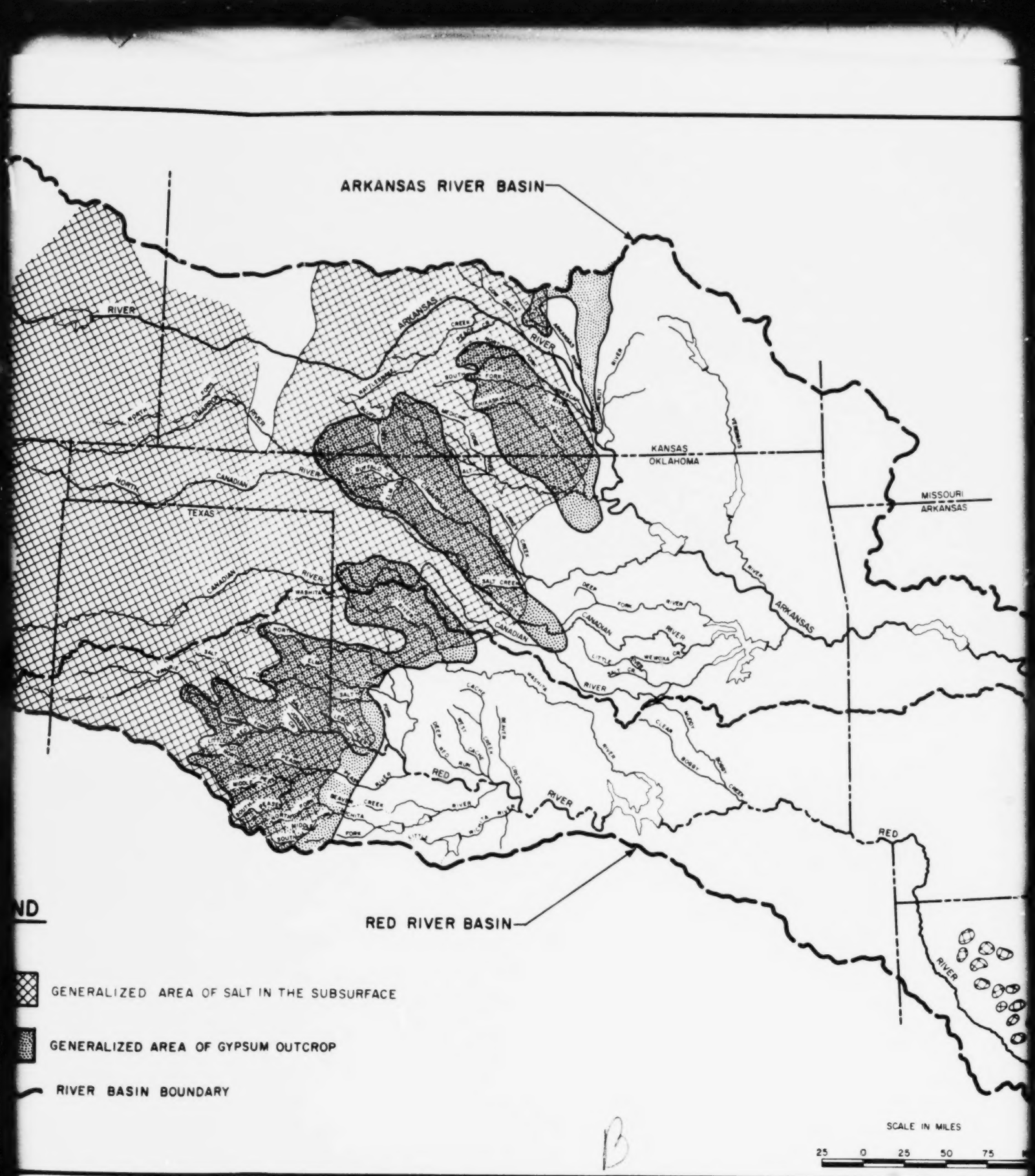
GENERALIZED AREA OF SALT IN TH
GENERALIZED AREA OF GYPSUM OU
RIVER BASIN BOUNDARY


ARKANSAS RIVER BASIN
KANSAS
OKLAHOMA
TEXAS
MISSOURI
ARKANSAS
RED RIVER BASIN
RED
RIVER
ND
GENERALIZED AREA OF SALT IN THE SUBSURFACE
GENERALIZED AREA OF GYPSUM OUTCROP
RIVER BASIN BOUNDARY
SCALE IN MILES
25 0 25 50 75

ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

SALT AND GYPSUM AREAS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE V–1

VI. STUDY METHODS

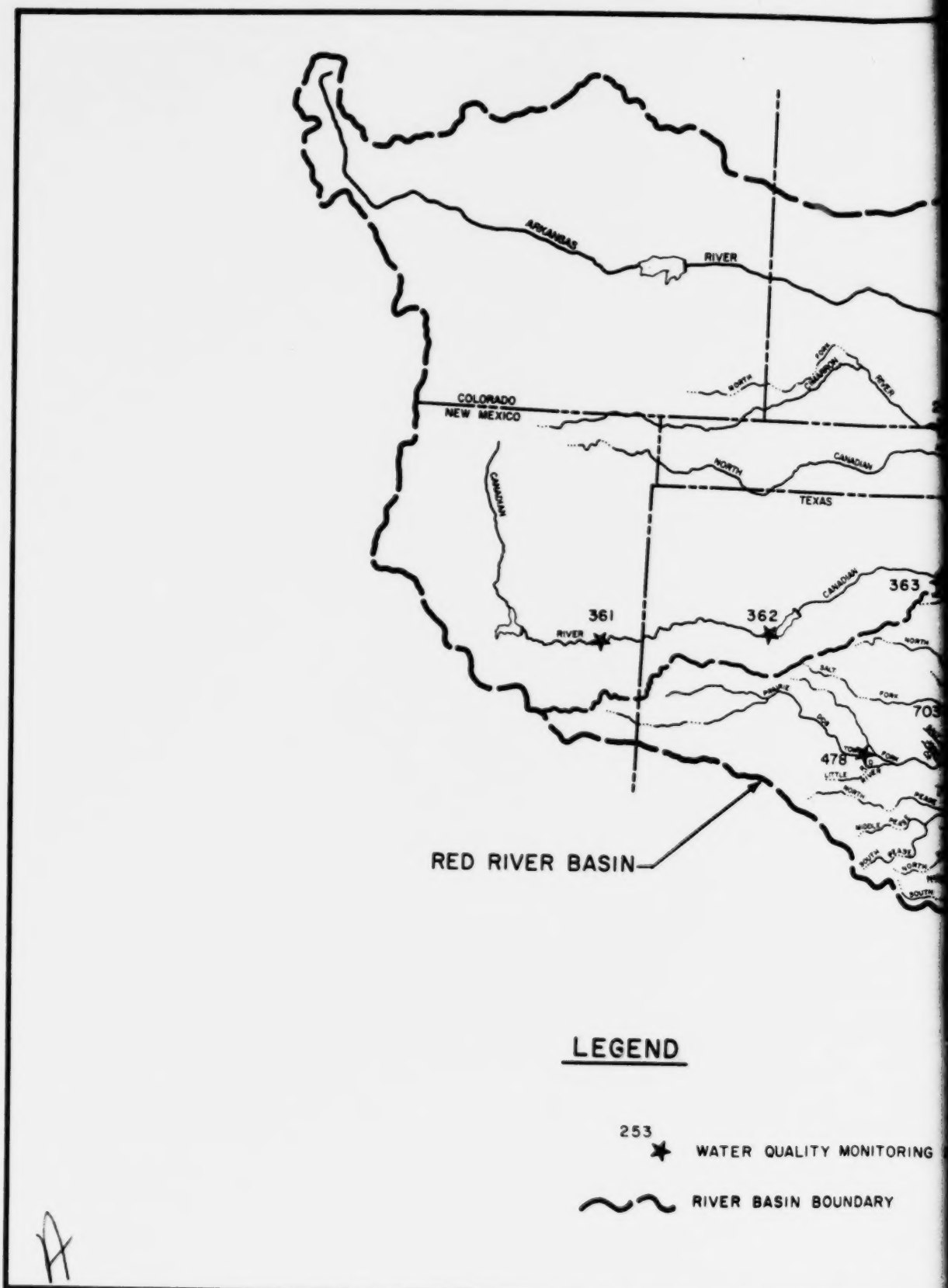
Personnel in the Public Health Service regional office in Dallas, Texas, working with State and local officials, and with the advice and guidance of a technical review committee, developed a study procedure for both basins. Sixty-four monitoring stations, thirty-seven on the Arkansas River and its tributaries and twenty-seven on the Red River system, were established for this 2-year field study. (Locations and designations are shown on Figure VI-1.)

The monitoring stations were located so that chloride and sulfate contributions from both natural and manmade sources, including gas and oil production could be measured. Wherever possible, the stations were established where streamflow gaging stations existed.

Because this study covered only a relatively short period of time and because of the sudden brief variations in salt load during rainy periods, especially at upstream stations with low flows, continuous monitoring was considered necessary. Electrical conductance recorders, suitable for continuous mineral content monitoring, were installed at all sixty-four monitoring sites during the late spring and early summer of 1960.

Chemical analyses of grab samples taken at monitoring stations showed reasonably good correlation between chlorides and conductance. Acceptable correlation was also demonstrated for sulfates at most stations. Grab samples were collected at least weekly and the results of laboratory analyses for conductance, chloride, sulfate, and dissolved solids were used in computing the correlations.

Streamflow hydrographs are necessary for computing daily or instantaneous tonnage of chloride, sulfate, and dissolved solids. Twenty-five additional flow gaging stations were, therefore, installed to augment existing stations. All of the new stations were installed and operated by the Geological Survey, Surface Water Branch, and, where possible, were established to serve the needs of other Federal, State, or local agencies. The Oklahoma, New Mexico, Kansas, Texas, and Arkansas district offices of the Geological Survey, Surface Water Branch, and the Corps of Engineers, Tulsa District, provided provisional (preliminary) subdivided daily streamflow reports for each station so that a flow hydrograph could be reproduced.


ARKANSAS
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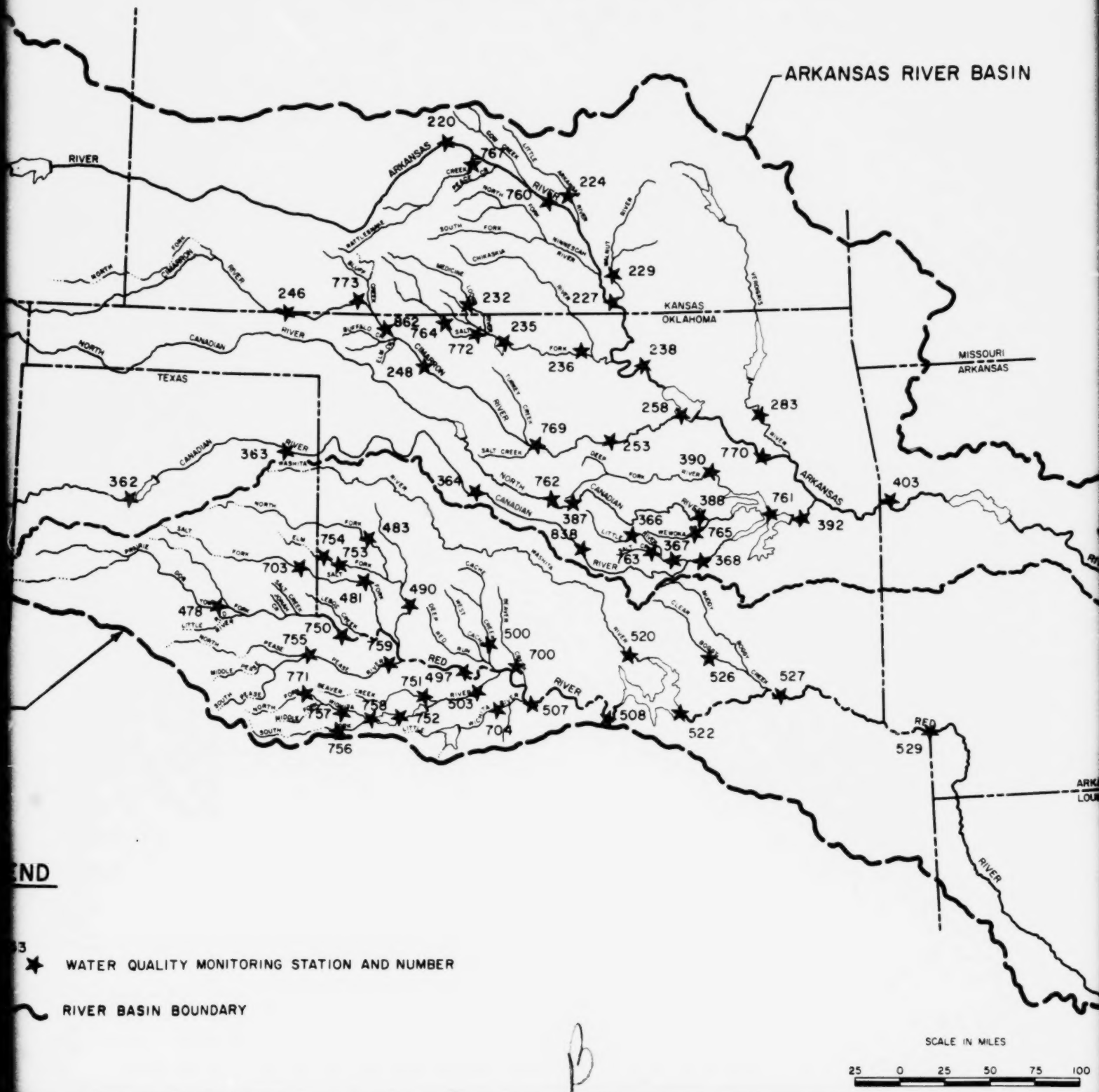
COLORADO
NEW MEXICO
NORTH
CANADIAN
RIVER
TEXAS
CANADIAN
361
RIVER
362
363
703
478
RED RIVER BASIN
LEGEND
253
WATER QUALITY MONITORING
RIVER BASIN BOUNDARY


ARKANSAS RIVER BASIN
KANSAS
OKLAHOMA
TEXAS
MISSOURI
ARKANSAS
ARKANSAS RIVER
CANADIAN RIVER
NORTH CANADIAN RIVER
CIMARRON RIVER
RED RIVER
WASHITA RIVER
SALT FORK RED RIVER
NORTH FORK RED RIVER
WEST CACHE CREEK
CACHE CREEK
DEEP RED RUN
LITTLE RED RIVER
NORTH FORK CANADIAN RIVER
SALT FORK ARKANSAS RIVER
NORTH FORK ARKANSAS RIVER
SOUTH FORK ARKANSAS RIVER
BIG CREEK
LITTLE ARKANSAS RIVER
BIG BLUE RIVER
WALNUT RIVER
VERDIGRIS RIVER
NEOSHO RIVER
CLEAR BOGGY CREEK
SALT CREEK
DEER CREEK
TIMBER CREEK
BUFFALO CREEK
LOCO CREEK
MEDICINE LODGE RIVER
CHIKASKIA RIVER
BLACK BEAVER CREEK
WEATHERFORD
LEXINGTON
PERRY
STILLWATER
PONCA CITY
ENID
HENNESSEY
KINGFISHER
CHICKASHA
ANADARKO
HOBART
ELK CITY
SAYRE
CLINTON
ALTUS
HOLLIS
HEALDTON
ARDMORE
DURANT
MADILL
TISHOMINGO
WAURIKA
HUGO
IDABEL
MANGUM
HEAVENER
WILBURTON
POTEAU
MCALESTER
STIGLER
SALLISAW
MUSKOGEE
TAHLEQUAH
WAGONER
PRYOR
VINITA
GROVE
MIAMI
COFFEYVILLE
CHANUTE
PARSONS
INDEPENDENCE
OSAGE
PAWHUSKA
BARTLESVILLE
NOWATA
CHEROKEE
ENID
220
761
224
760
229
773
246
232
227
862
764
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772
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283
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704
522
756
529
LEGEND
WATER QUALITY MONITORING STATION AND NUMBER
RIVER BASIN BOUNDARY
SCALE IN MILES
25 0 25 50 75 100

ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

WATER QUALITY MONITORING STATIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VI – 1

Location and Measurement of Natural Salt Emissions

Natural salt water emission areas were located from published and unpublished reports. Airplane surveys were made to pinpoint reported sources and locate others. Field investigations of each source were undertaken to locate and define specific springs, seeps, and other brine drainage areas. Brine flows and concentrations were determined for each salt source area and, where possible, individual emissions in an area were measured. As stated above, where feasible, a continuous conductivity recorder station was operated downstream to measure the salt load, its variations, and its effects on the stream.

Manmade Salt Sources

Estimates of salt discharged from oil and gas operations as well as information regarding disposal practices were obtained from the State agencies responsible for these practices.

VII. RESULTS OF FIELD STUDY

In any pollution study, the volume or rate of streamflow is an important factor in the determination of the pollutant loads (tons) and the average water quality. In general, higher flows carry larger loads of minerals but with lower concentrations.

Long-term streamflow gaging stations were located downstream from two of the natural brine sources in the Arkansas River basin. Results at these stations and other stations in the two basins were used to compare the flows observed during the study period with long-run averages. The flow below the Great Salt Plains on the Salt Fork of the Arkansas River near Jet, Oklahoma, during 1961 and 1962, was about average; the flow in the Cimarron River near Waynoka, Oklahoma, was about 60 percent of the long-term average. The 2-year average flow in the Arkansas River at Van Buren, Arkansas, was 20 percent larger than the long-term average, with most of excess above average flow contributed by the better quality tributaries in eastern Oklahoma. The streamflows and rainfall in the vicinities of other significant natural salt sources appear to have been about average. The flow in the Red River into Lake Texoma was slightly below average.

The long-term average flows and the annual average flows for the period of intensive study (1961-62 water years) are summarized in Tables VII-1 and VII-2.

Stream Quality

Weighted values shown in this report are based on a time, flow, and continuously recorded specific conductance relationship. Through the use of correlation equations, derived from laboratory analyses of weekly grab samples, and this weighted average specific conductance, average mineral constituent concentrations in mg/l were computed. From the average concentration and the discharge monitored during periods of recorded specific conductance, average loads are computed.

Average annual and daily streamflows and average annual and daily concentrations of chlorides, sulfates, and dissolved solids, for the water years 1961 and 1962 (October 1960--September 1962), for each monitoring station, are shown on Figures VII-1 and VII-2, while average loads, in tons per day, are shown on Figures VII-3 and VII-4.

Four reservoirs (three in the Red River system and one in the Arkansas River system) affecting water quality were included in the monitoring network. Inflow into each reservoir differed from the outflow, both in amount and quality and also represented different periods of time. Because capacity in each reservoir equaled or exceeded the average annual streamflow into the reservoir, the time required for flow through each reservoir was a year or more.

Table VII-1

Comparison of Flows During Study With
Long-Term Average Annual Flows
Arkansas River

Station Number and Location	Years of Record	Annual Average Streamflow (cfs) Long-Term*	1961-1962 Water Years
220 - Arkansas River near Great Bend, Kansas	22	453	257
224 - Little Arkansas River at Valley Center, Kansas	40	252	493
227 - Arkansas River at Arkansas City, Kansas	45	1,782	2,625
229 - Walnut River at Winfield, Kansas	41	765	1,548
232 - Medicine Lodge River near Kiowa, Kansas	17	154	102
235 - Salt Fork of Arkansas River near Jet, Oklahoma	25	404	364
236 - Salt Fork of Arkansas River near Tonkawa, Oklahoma	27	713	323
238 - Arkansas River at Ralston, Oklahoma	37	4,749	7,268
246 - Cimarron River near Mocane, Oklahoma	20	100	81
248 - Cimarron River near Waynoka, Oklahoma	25	420	272
253 - Cimarron River near Perkins, Oklahoma	23	1,293	1,406
258 - Cimarron River near Mannford, Oklahoma	15	1,785	1,889
283 - Verdigris River near Inola, Oklahoma	18	4,483	7,488
361 - Canadian River at Logan, New Mexico	34	308	170
362 - Canadian River near Amarillo, Texas	24	463	280
363 - Canadian River near Canadian, Texas	24	590	269
364 - Canadian River near Bridgeport, Oklahoma	18	507	476
366 - Little River near Tecumseh, Oklahoma	19	160	107
367 - Little River near Sasakwa, Oklahoma	20	440	245
368 - Canadian River at Calvin, Oklahoma	23	1,972	1,388
387 - North Canadian River near Oklahoma City, Oklahoma	16	380	268
388 - North Canadian River near Wetumka, Oklahoma	25	771	525
390 - Deep Fork near Beggs, Oklahoma	24	909	715
392 - Canadian River near Whitefield, Oklahoma	24	6,173	4,520
403 - Arkansas River at Van Buren, Arkansas	35	32,080	38,900
762 - North Canadian River below Lake Overholser, Okla.	10	149	169
770 - Arkansas River at Haskell, Oklahoma	37	6,750	10,100
772 - Salt Fork of Arkansas River at Ingersoll, Oklahoma	11	366	90

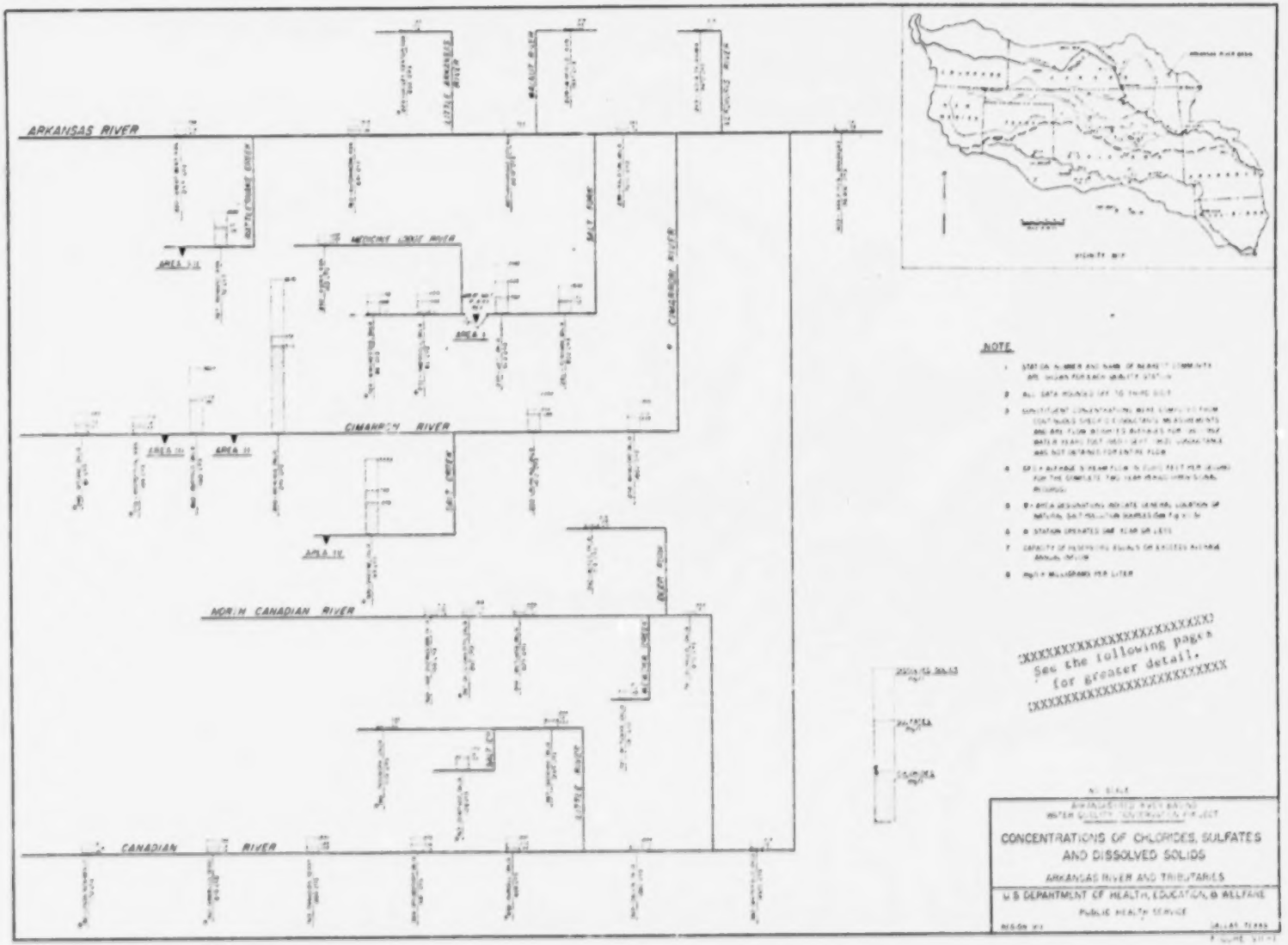
* Source: Geological Survey 15/

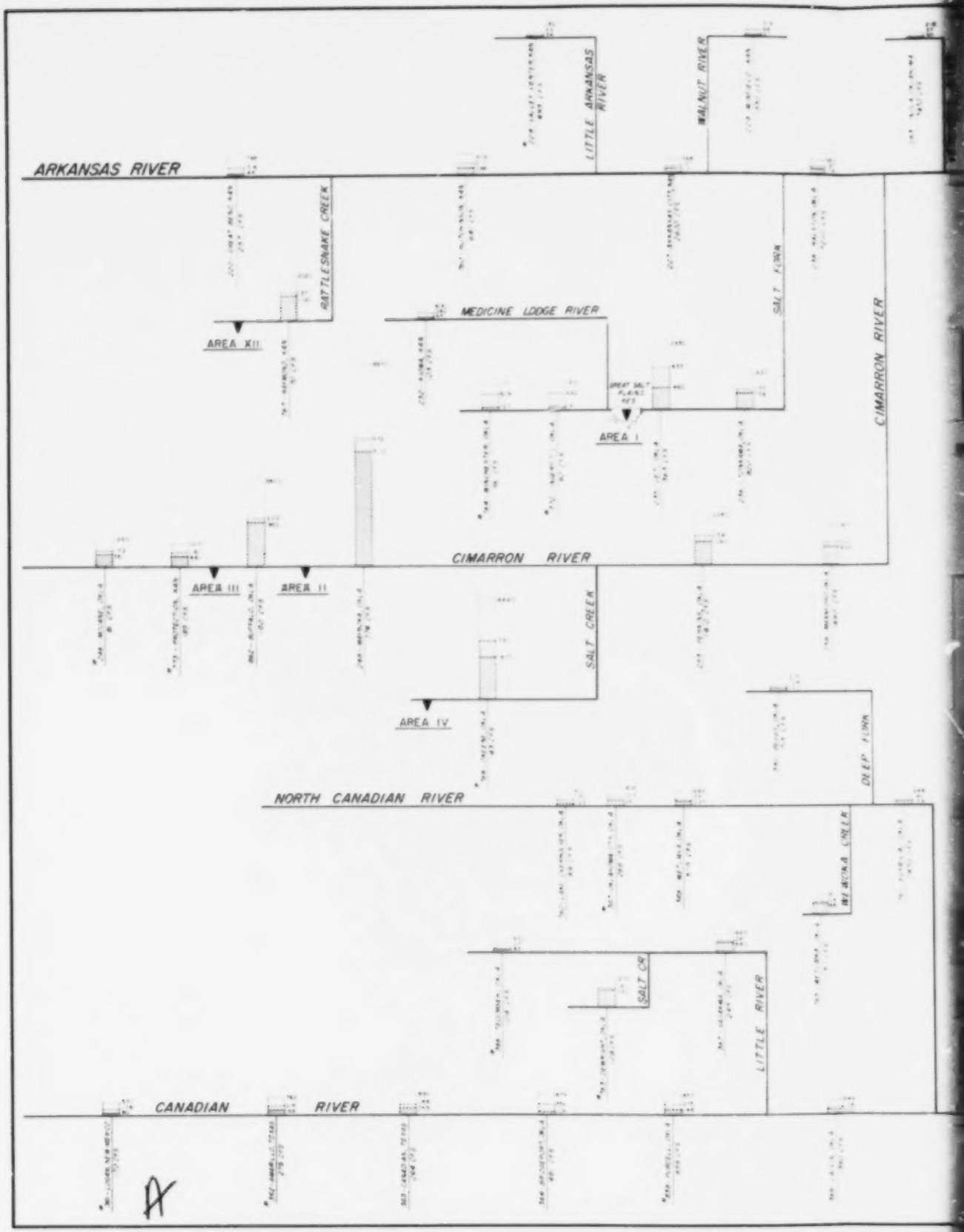
Table VII-2

Comparison of Flows During Study with
Long-Term Average Annual Flows
Red River

Station Number and Location	Record	Annual Average Streamflow (cfs) Long-Term*	1961-1962 Water Years
478 - Red River near Brice, Texas	7	85	71
481 - Salt Fork of Red River at Mangum, Oklahoma	25	97	124
483 - North Fork of Red River near Carter, Oklahoma	18	138	215
490 - North Fork of Red River near Headrick, Oklahoma	27	347	508
500 - Cache Creek near Walters, Oklahoma	24	188	246
503 - Wichita River at Wichita Falls, Texas	25	324	288
507 - Red River near Terral, Oklahoma	24	2,567	2,420
508 - Red River near Gainesville, Texas	26	3,168	2,820
520 - Washita River near Durwood, Oklahoma	34	1,526	1,245
522 - Red River near Colbert, Oklahoma (Denison Dam)	39	5,201	4,320
526 - Clear Boggy Creek near Caney, Oklahoma	20	497	321
527 - Red River at Arthur City, Texas	32	8,672	7,090
529 - Red River at Index, Oklahoma	26	12,680	10,600
700 - Beaver Creek near Waurika, Oklahoma	9	152	164
703 - Salt Fork of Red River near Wellington, Texas	10	91	89
704 - Little Wichita River near Henrietta, Texas	9	134	79

* Source: Geological Survey 15/


ARKANSAS RIVER
CIMARRON RIVER
NORTH CANADIAN RIVER
CANADIAN RIVER
AREA I
AREA II
AREA III
AREA IV
MEDICINE LODGE RIVER
NOTE
See the following page
for greater detail.
CONCENTRATIONS OF CHLORIDES, SULFATES
AND DISSOLVED SOLIDS
ARKANSAS RIVER AND TRIBUTARIES
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE


ARKANSAS RIVER
LITTLE ARKANSAS RIVER
WALNUT RIVER
RATTLESNAKE CREEK
AREA XII
MEDICINE LODGE RIVER
SALT FORK
CIMARRON RIVER
AREA I
CIMARRON RIVER
AREA III
AREA II
SALT CREEK
AREA IV
DEEP FORK
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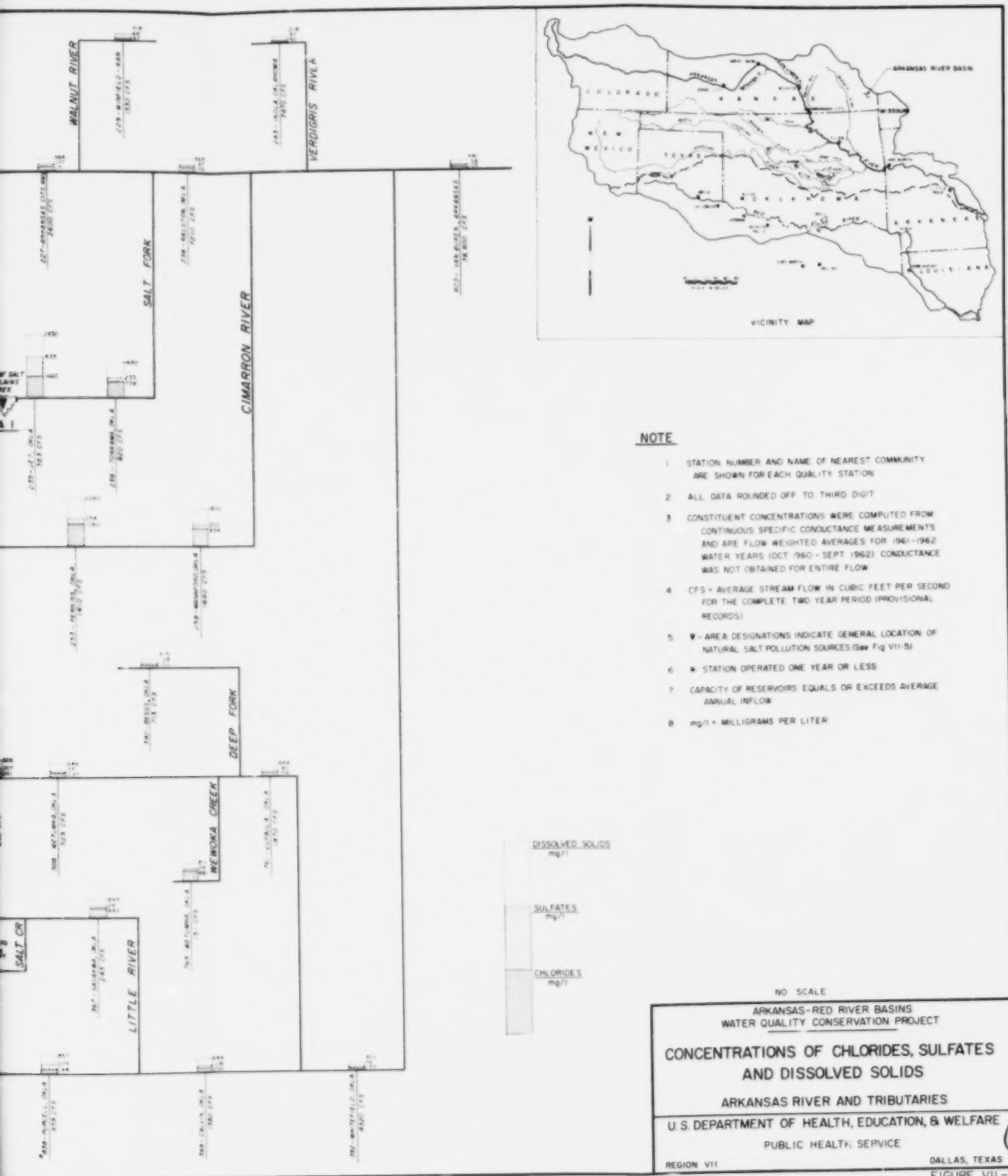
BIG BEAVER CREEK
SALT CR
LITTLE RIVER
CANADIAN RIVER
A



VICINITY MAP

NOTE

1. STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2. ALL DATA ROUNDED OFF TO THIRD DIGIT
3. CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1962 WATER YEARS (OCT. 1960 - SEPT. 1962). CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. ▼ - AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (See Fig. VII-5)
6. * STATION OPERATED ONE YEAR OR LESS
7. CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW
8. mg/l = MILLIGRAMS PER LITER

NO SCALE

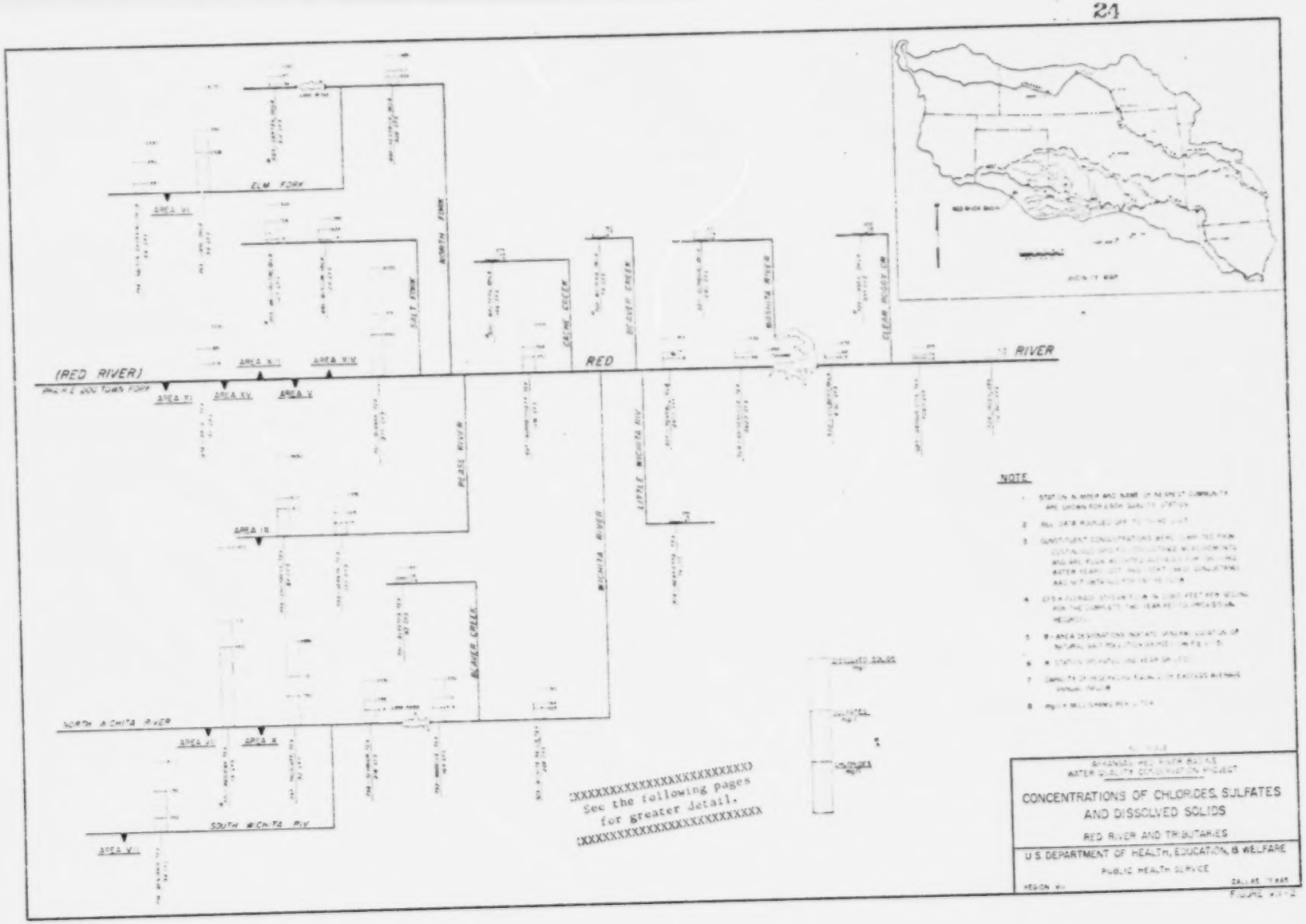
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

CONCENTRATIONS OF CHLORIDES, SULFATES AND DISSOLVED SOLIDS

ARKANSAS RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII — DALLAS, TEXAS

FIGURE VII-1



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See the following pages
for greater detail.
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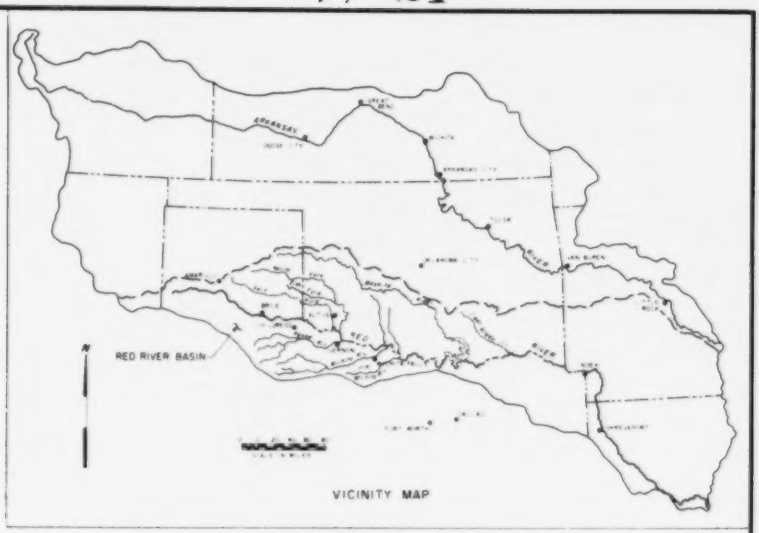
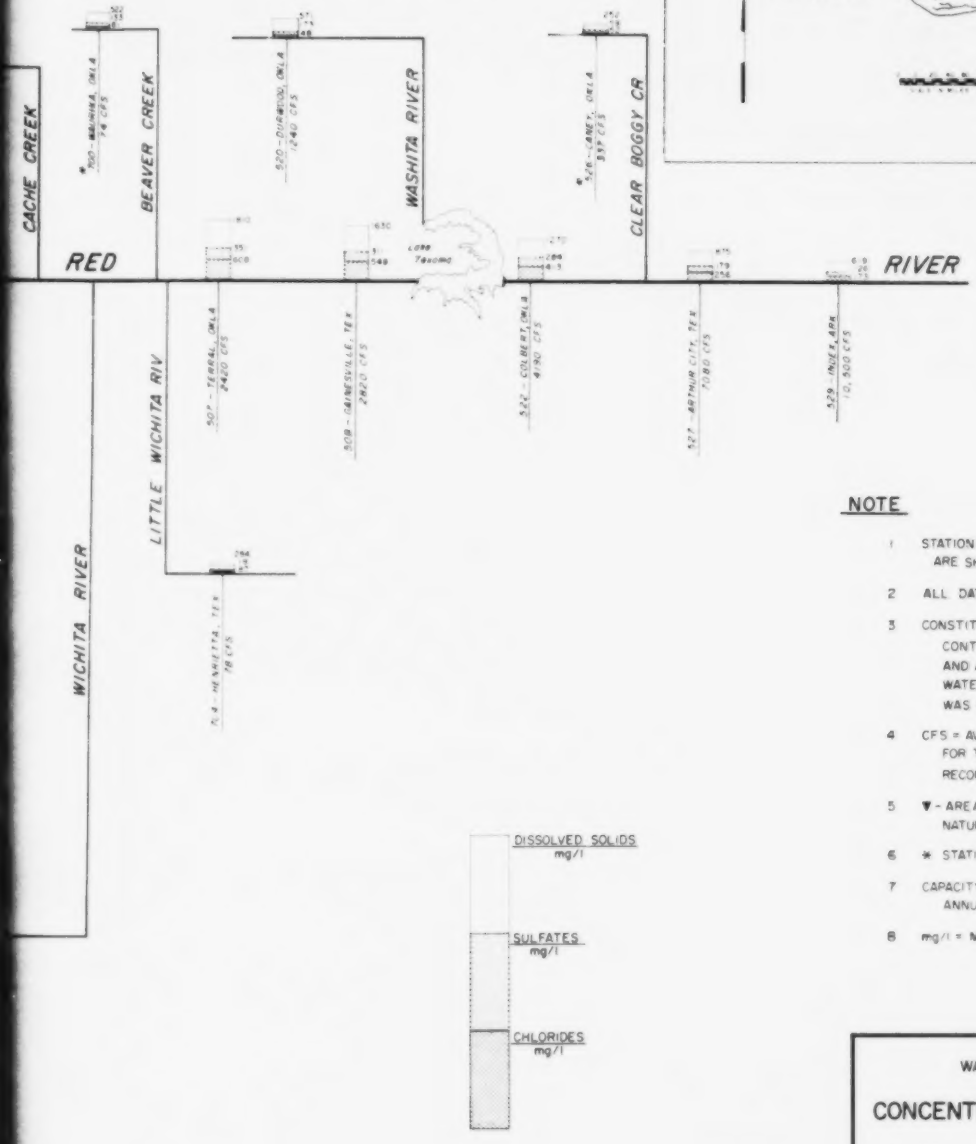
ELM FORK
AREA I
NORTH FORK
(RED RIVER)
PRAIRIE DOG TOWN FORK
AREA V
AREA VI
AREA I
RED
NORTH WICHITA RIVER
AREA VII
AREA X
SOUTH WICHITA R.
AREA VIII





NOTE

1. STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2. ALL DATA ROUNDED OFF TO THIRD DIGIT
3. CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1962 WATER YEARS (OCT 1960 - SEPT 1962) CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. ▼ - AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (See Fig. VII-5)
6. * STATION OPERATED ONE YEAR OR LESS
7. CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW
8. mg/l = MILLIGRAMS PER LITER

NO SCALE

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

CONCENTRATIONS OF CHLORIDES, SULFATES AND DISSOLVED SOLIDS

RED RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VII-2

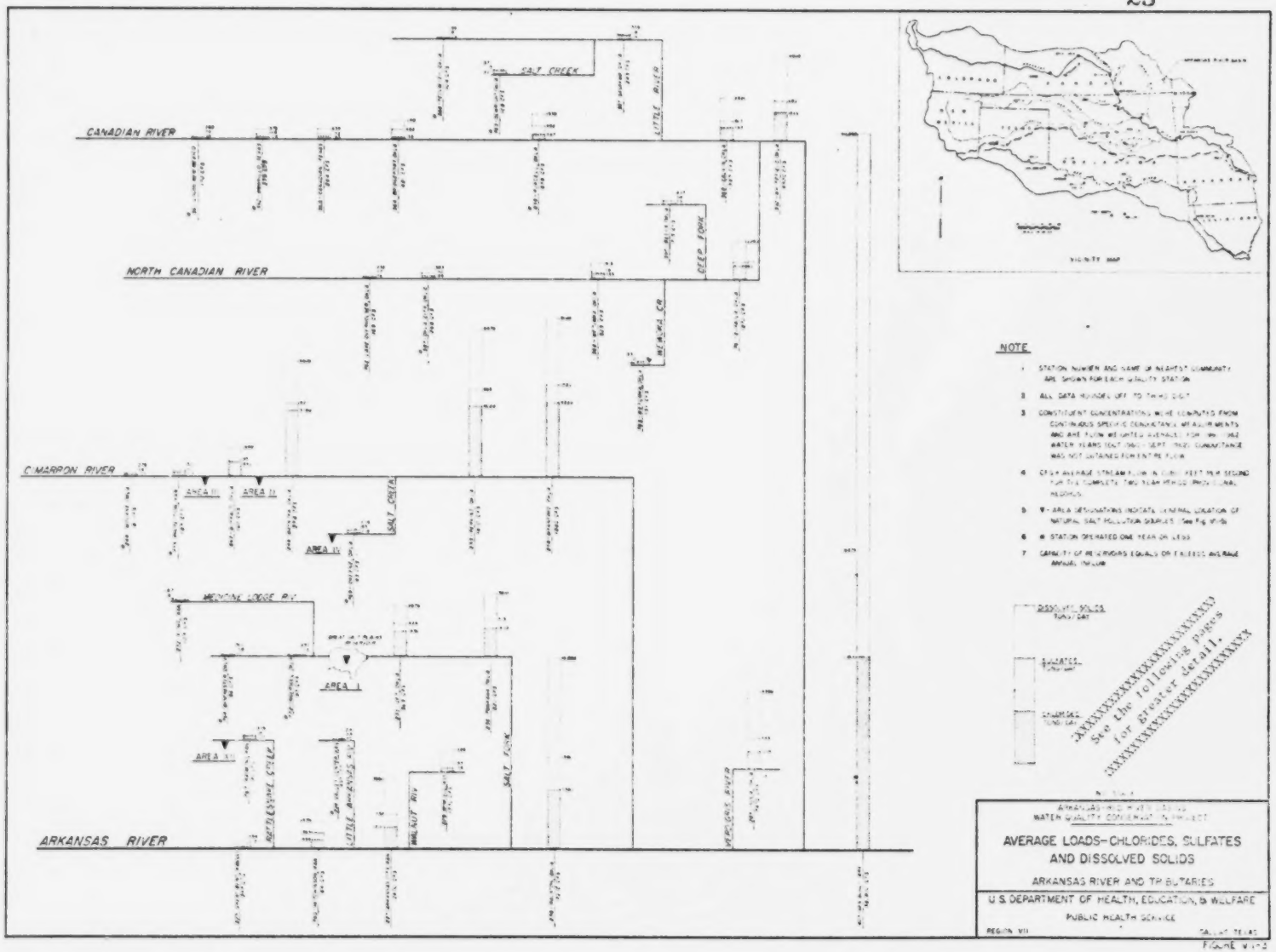
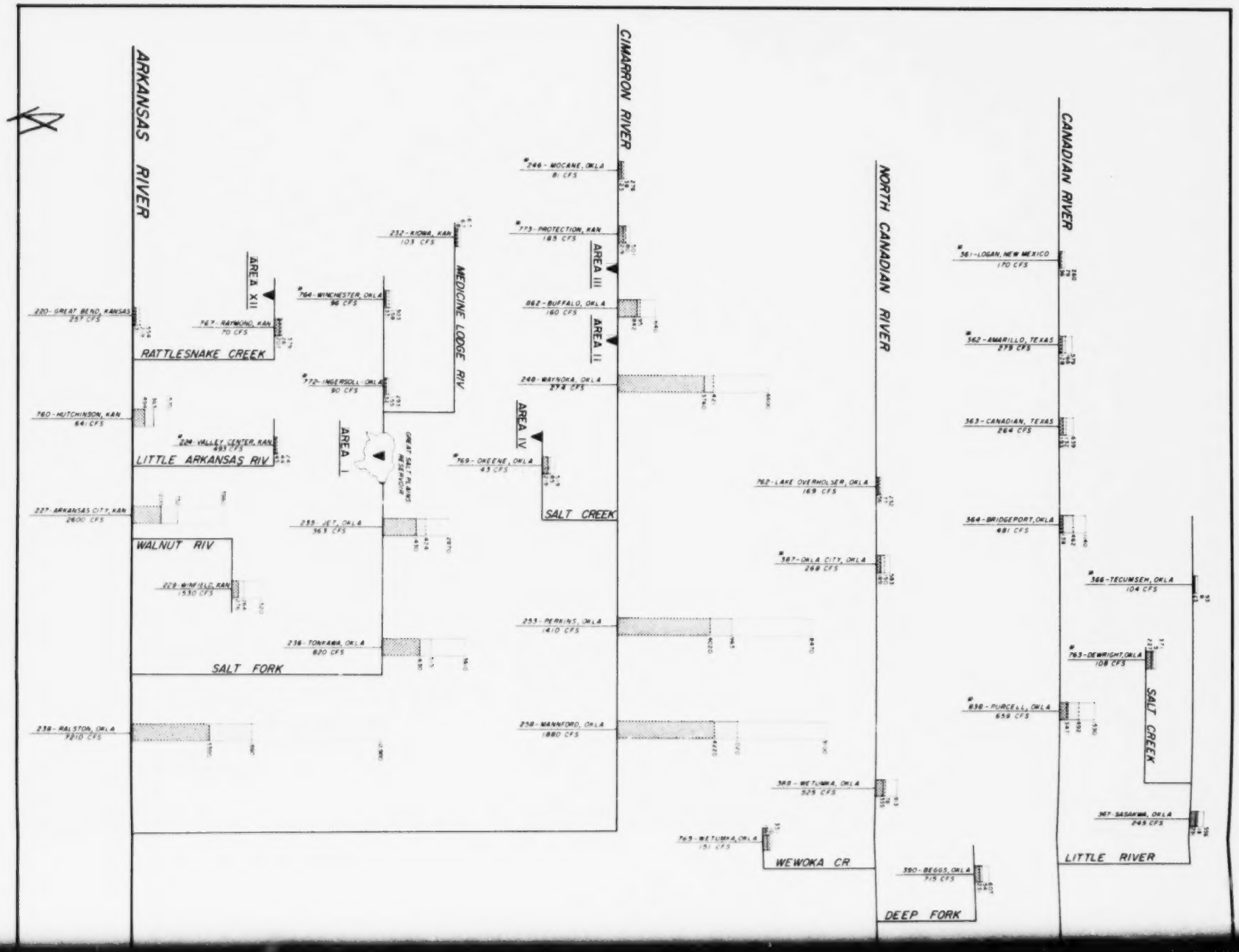
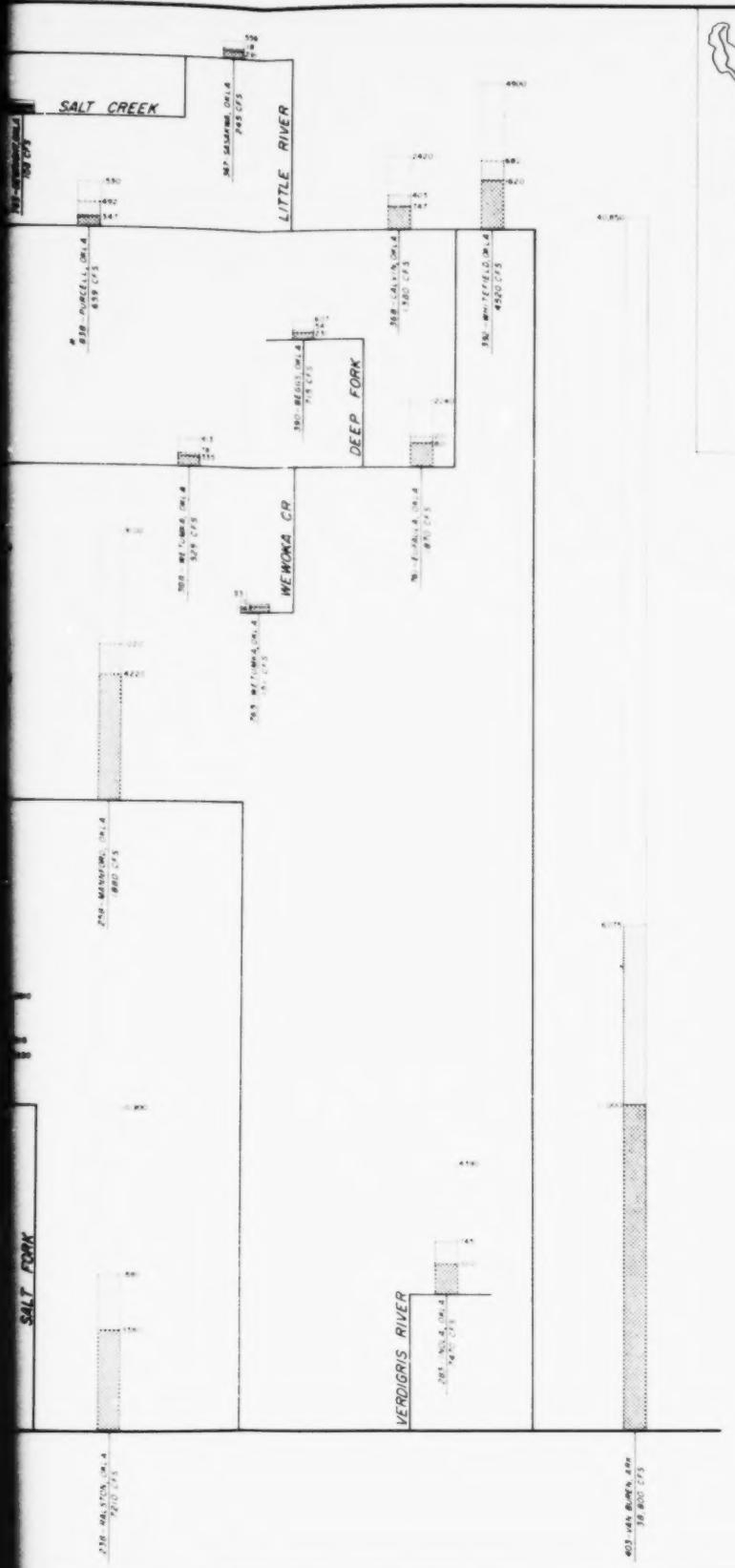
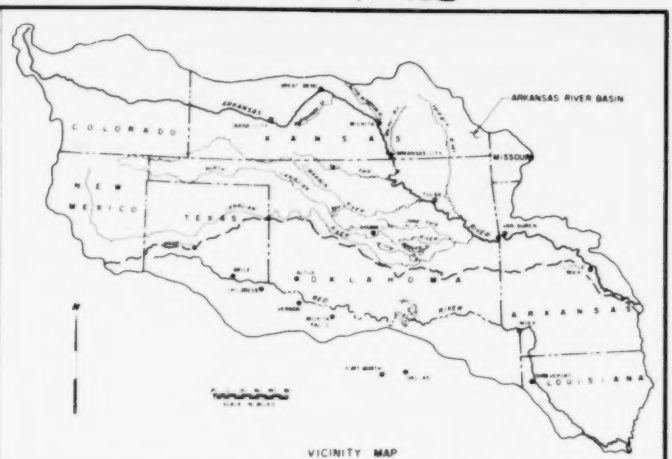

SALT CREEK
CANADIAN RIVER
NORTH CANADIAN RIVER
DEEP FORK
C. MARRON RIVER
AREA III
AREA II
AREA IV
SALT CREEK
MEDICINE LODGE R.V.
AREA I
AREA V
SALT FORK
ARKANSAS RIVER
NOTE
1 STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2 ALL DATA ROUNDED OFF TO THREE DIGIT
3 CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND DAILY FLOW WEIGHTED AVERAGES FOR WATER YEARS 1957 THROUGH SEPT 1962 CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4 CFSA AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE 1962 YEAR WHERE PRACTICAL RECORDS
5 V - ARLA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (See Fig VI-5)
6 # STATION OPERATED ONE YEAR OR LESS
7 CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW
DISSOLVED SOLIDS TONS/DAY
SULFATES TONS/DAY
CHLORIDES TONS/DAY
See the following pages for greater detail.
AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS
ARKANSAS RIVER AND TRIBUTARIES
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII

FIGURE VI-12


ARKANSAS RIVER
CIMARRON RIVER
NORTH CANADIAN RIVER
CANADIAN RIVER
RATTLESNAKE CREEK
MEDICINE LODGE RIV
LITTLE ARKANSAS RIV
WALNUT RIV
SALT FORK
SALT CREEK
WEWOKA CR
DEEP FORK
LITTLE RIVER
SALT CREEK
AREA I
AREA II
AREA III
AREA IV
AREA XIII
GREAT SALT PLAINS RESERVOIR
220 - GREAT BEND, KANSAS 257 CFS
760 - HUTCHINSON, KAN 641 CFS
224 - VALLEY CENTER, KAN 493 CFS
227 - ARKANSAS CITY, KAN 2600 CFS
228 - WINFIELD, KAN 1530 CFS
239 - RALSTON, OKLA 7810 CFS
767 - RAYMOND, KAN 70 CFS
764 - WINCHESTER, OKLA 96 CFS
772 - INGERSOLL, OKLA 90 CFS
232 - KIOWA, KAN 103 CFS
235 - JET, OKLA 565 CFS
236 - TONKAWA, OKLA 820 CFS
246 - MOCANE, OKLA 81 CFS
773 - PROTECTION, KAN 185 CFS
862 - BUFFALO, OKLA 160 CFS
248 - WAYNOKA, OKLA 274 CFS
769 - OKEENE, OKLA 45 CFS
253 - PERKINS, OKLA 1410 CFS
258 - MANNFORD, OKLA 1880 CFS
762 - LAKE OVERHOLSER, OKLA 169 CFS
387 - OKLA CITY, OKLA 268 CFS
388 - WETUMKA, OKLA 525 CFS
769 - WETUMKA, OKLA 151 CFS
390 - BEGGS, OKLA 715 CFS
361 - LOGAN, NEW MEXICO 170 CFS
362 - AMARILLO, TEXAS 278 CFS
363 - CANADIAN, TEXAS 264 CFS
364 - BRIDGEPORT, OKLA 481 CFS
366 - TECUMSEH, OKLA 104 CFS
763 - DEWRIGHT, OKLA 108 CFS
850 - PURCELL, OKLA 659 CFS
367 - SASAKWA, OKLA 249 CFS





VICINITY MAP

NOTE

1. STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2. ALL DATA ROUNDED OFF TO THIRD DIGIT
3. CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1962 WATER YEARS (OCT 1960 - SEPT 1962) CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. ▼ - AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (See Fig VII-5)
6. * STATION OPERATED ONE YEAR OR LESS
7. CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW

DISSOLVED SOLIDS
TONS / DAY

SULFATES
TONS/DAY

CHLORIDES
TONS/DAY

NO SCALE

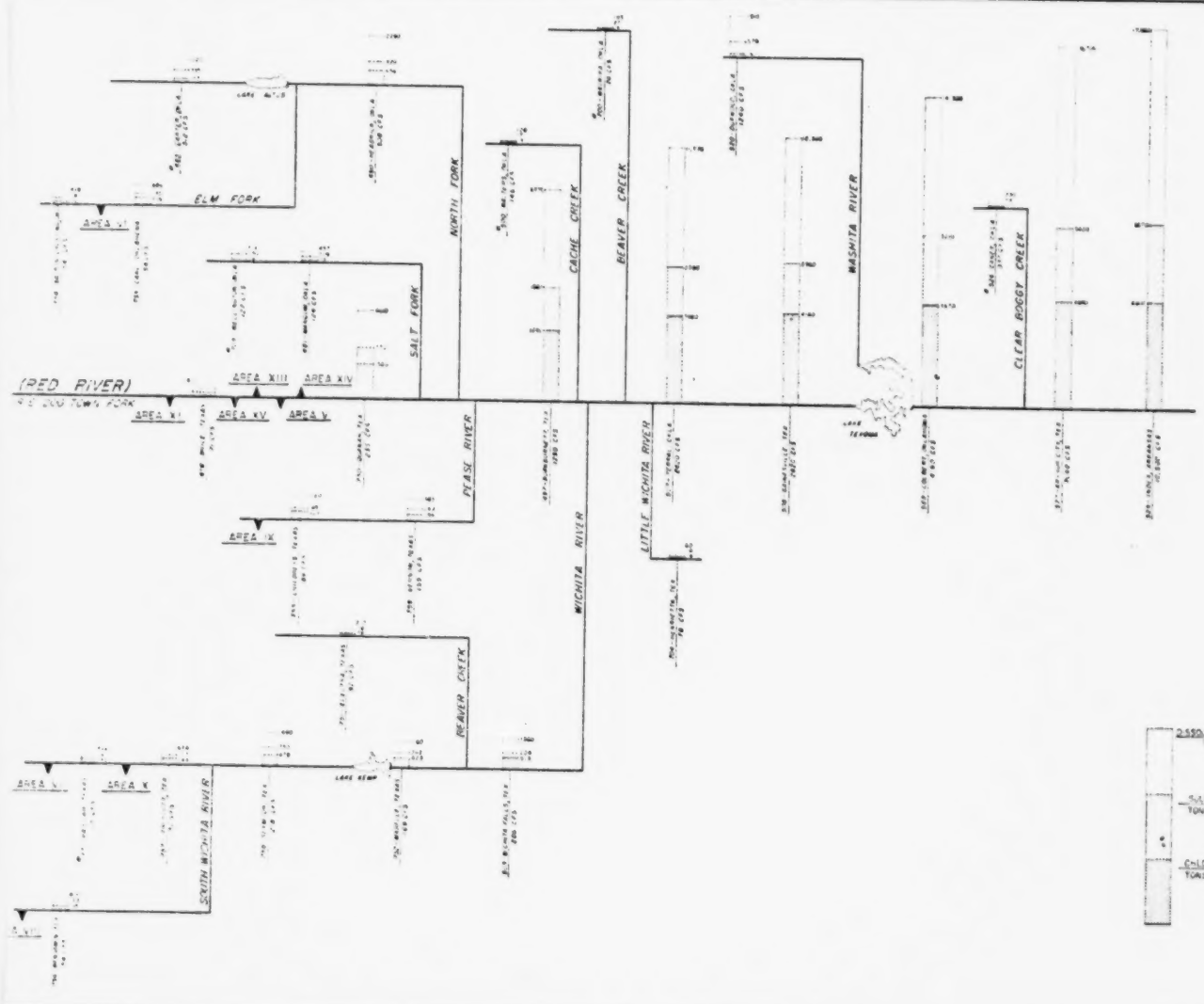
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

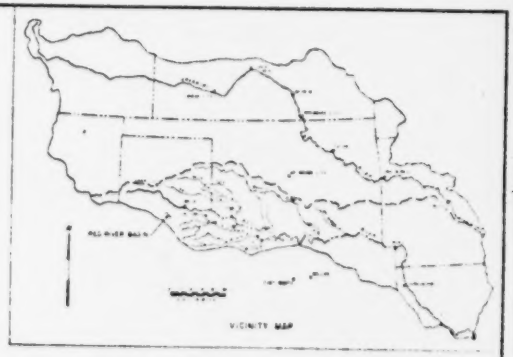
AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS

ARKANSAS RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII — DALLAS, TEXAS

FIGURE VII-3





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4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. W = AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (SEE FIG VIII-5)
6. W STATION OPERATES ONE YEAR OR LESS
7. CAPACITY OF RESERVOIR EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW

(XXXXXXXXXXXXXXXXXXXXXXX)
See the following pages
for greater detail.
(XXXXXXXXXXXXXXXXXXXXXXX

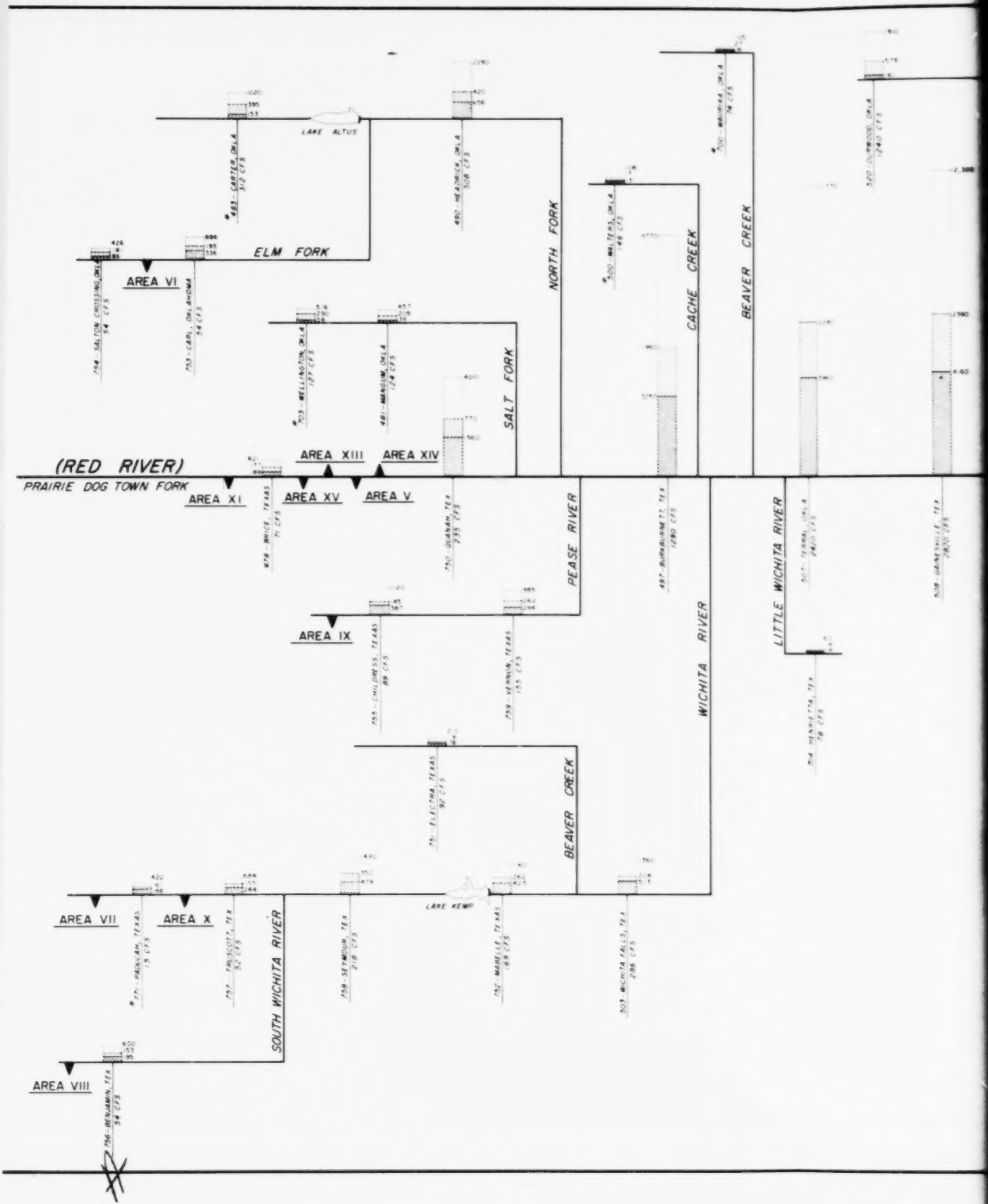
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

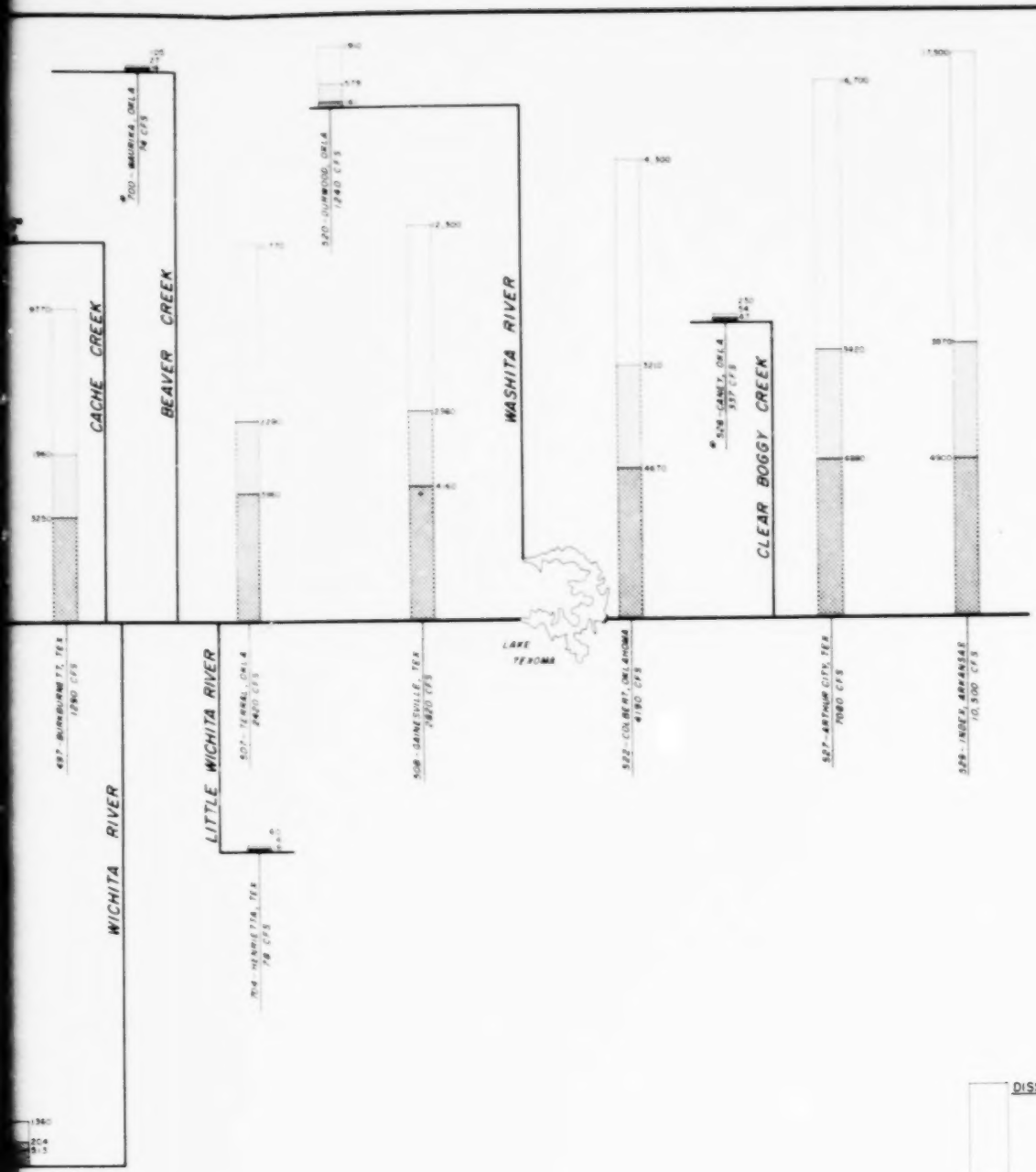
AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS

RED RIVER AND TRIBUTARIES

U S DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VIII-4


LAKE ALTUS
481 - CARTER, OKLA
512 CFS
480 - HEADRICK, OKLA
308 CFS
ELM FORK
NORTH FORK
AREA VI
754 - SALTON CROSSING, OKLA
54 CFS
753 - CARL, OKLAHOMA
54 CFS
703 - WELLINGTON, OKLA
127 CFS
481 - MANGUM, OKLA
124 CFS
SALT FORK
CACHE CREAM
BEAVER CREEK
(RED RIVER)
PRAIRIE DOG TOWN FORK
AREA XIII
AREA XIV
AREA XI
AREA XV
AREA V
478 - BRICE, TEXAS
71 CFS
752 - QUANAH, TEX
235 CFS
PEASE RIVER
497 - BURKBURNETT, TEX
1280 CFS
WICHITA RIVER
LITTLE WICHITA RIVER
507 - TERRAL, OKLA
2400 CFS
AREA IX
755 - CHILDRESS, TEXAS
69 CFS
759 - VERNON, TEXAS
135 CFS
754 - MANGUM, TEX
78 CFS
BEAVER CREEK
751 - ELECTRA, TEXAS
92 CFS
AREA VII
AREA X
LAKE KEMP
SOUTH WICHITA RIVER
770 - PADUCAH, TEXAS
75 CFS
757 - TRUSCOTT, TEX
52 CFS
758 - SEYMOUR, TEX
218 CFS
752 - MARGLE, TEXAS
169 CFS
503 - WICHITA FALLS, TEX
286 CFS
AREA VIII
756 - BENJAMIN, TEX
54 CFS



NOTE

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3 CONSTITUENT
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4 CFS = AVERAG
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NATURAL S

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7 CAPACITY OF
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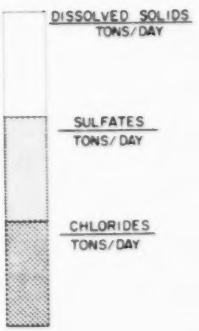

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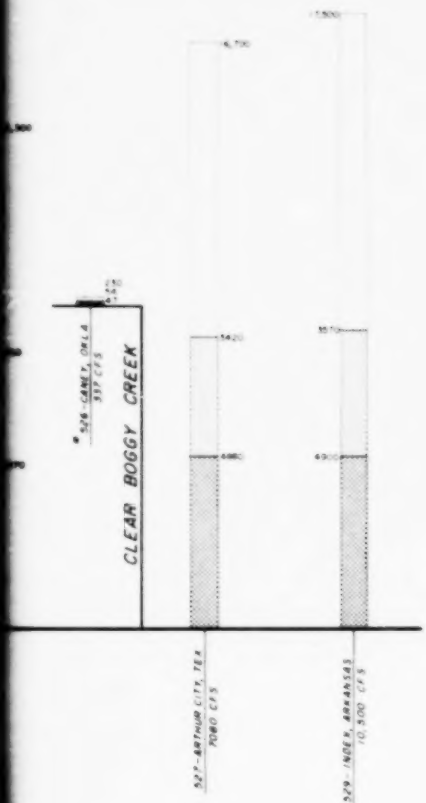
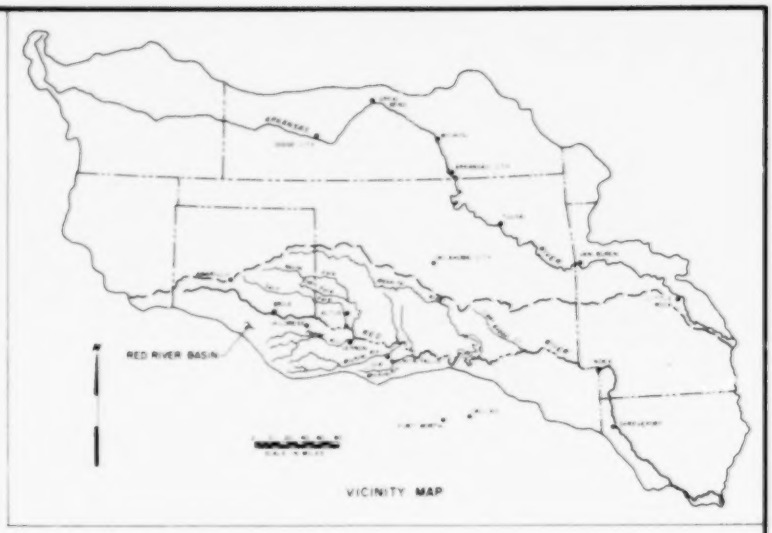
REGION VI

B





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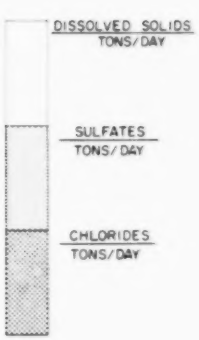


NO SCALE

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS

RED RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII — DALLAS, TEXAS

FIGURE VII-4

Also, because rainfall may be greater or less than evaporation, reservoir outflow might also be either more or less than inflow. To illustrate, the Great Salt Plains Reservoir (Arkansas River basin) contained 17,000 acre-feet less water on September 30, 1962, than on October 1, 1960, when the study started; Lake Kemp contained 73,000 acre-feet more; and Lake Texoma on the Red River, 109,000 acre-feet more. Detention and mixing in the reservoirs eliminated the effects of sharp upstream variations in quality. Below the reservoirs, the quality has tended to be more uniform.

The average chloride concentrations of the Arkansas River at Tulsa exceeded 250 mg/l. However, large quantities of water had a lower chloride concentration during brief periods of very high flow rates. This was also true of the Red River above Gainesville, Texas. Tables VII-3 and VII-4 show the changes in water quality in terms of specific conductance as related to acre-feet and percent of the total quantity.

Table VII-3 indicates that, for the water year from October 1961 to September 1962, 90 percent of the total flow or 22.2 million acre-feet of water in the Arkansas River at Van Buren, Arkansas, was of acceptable quality, as indicated by an average specific conductance of 1,000 micromhos or less. In the Red River at Index, Arkansas, for the same period, Table VII-4 shows that 55 percent or 4.5 million acre-feet was of acceptable quality (i.e., 1,000 micromhos or less). While the relationship varies from stream to stream, during the study in the Arkansas Red River basins area 1,000 micromhos water represented a chloride content between extremes of 44 and 361 mg/l as Cl and a dissolved solids content from 560 to 850 mg/l. A chloride concentration of 250 mg/l or less was indicated by a specific conductance of 1,000 micromhos at 90 percent of the stations.

From these data it appears that there is an abundance of water of acceptable quality available. However, under present conditions 80 to 90 percent of the streamflow for the entire year may pass Van Buren and Index, Arkansas in a single 2- to 4-month period, with 10 to 20 percent being distributed over the remaining 8 to 10 months. Therefore, during the major portions of each year, the quality may be unsatisfactory. One problem is to make an abundance of water of acceptable quality available when and where it is needed.

Natural Salt Sources

Field investigations and monitoring stations data show that there are fifteen primary natural salt sources with a total daily salt emission of approximately 13,000 tons per day as sodium chloride. As shown in Table VII-5, and illustrated on Figure VII-5, ten of these sources are in the Red River basin and five in the Arkansas River basin.

Table VII-3

Arkansas River Basin - Selected Stations
Quantity and Percentage of Water of Various Qualities
(October 1960 - September 1962)

Station No. Stream Location	Total Flow (Ac.-Ft.)	Acre-Feet of Water (and % of Total) of Following Specific Conductance, Micromhos/cm² * 0-500	500-1,000	1,000-1,500	1,500-2,500	2,500-5,000	5,000-10,000	10,000-30,000
(Water Year 1961)**								
220 Arkansas River at Great Bend, Kans.	136,700	43,800 32.0%	29,700 21.7%	50,700 37.1%	12,500 9.2%	31 0%	4 0%	0 0%
227 Arkansas River at Arkansas City, Kans.	1,719,000	560,500 32.6%	446,100 26.0%	275,200 16.0%	436,500 25.4%	793 0%	0 0%	0 0%
238 Arkansas River at Ralston, Okla.	5,430,000	2,155,000 39.7%	1,354,000 24.9%	969,900 17.9%	949,200 17.5%	2,740 0%	0 0%	0 0%
403 Arkansas River at Van Buren, Ark.	31,590,000	18,288,600 57.9%	10,558,200 33.5%	2,465,000 7.8%	279,500 .8%	0 0%	0 0%	0 0%
229 Walnut River at Winfield, Kans.	1,202,000	781,700 65.0%	285,300 23.7%	106,800 8.9%	28,400 2.4%	0 0%	0 0%	0 0%
236 Salt Fork of Ark. River at Tonkawa, Okla.	670,600	49,500 7.4%	65,300 9.7%	86,700 12.9%	120,700 18,0%	333,200 49.7%	15,200 2.3%	0 0%

Table VII-3 (Continued)

Station No. Stream Location	Total Flow (Ac.-Ft.)	Acre-Feet of Water (and % of Total) of Following Specific Conductance, Micromhos/cm² *						
		0-500	500-1,000	1,000-1,500	1,500-2,500	2,500-5,000	5,000-10,000	10,000-30,000
253 Cimarron River at Perkins, Okla.	1,051,000	151,600 14.4%	117,400 11.2%	123,700 11.8%	145,200 13.8%	225,800 21.5%	242,700 23.1%	44,500 4.2%
283 Verdigris River near Inola, Okla.	6,495,000	6,060,000 93.3%	426,500 6.6%	8,540 .1%	8 0%	0 0%	0 0%	0 0%
392 Canadian River at Whitefield, Okla.	3,169,000	1,072,000 33.8%	1,481,000 46.7%	566,300 17.9%	49,700 1.6%	0 0%	0 0%	0 0%
(Water Year 1962)***								
220 Arkansas River at Great Bend, Kans.	236,200	97,000 41.1%	39,700 16.8%	26,800 11.3%	55,400 23.5%	17,300 7.3%	0 0%	0 0%
227 Arkansas River at Arkansas City, Kans.	2,055,000	794,000 38.7%	486,900 23.7%	253,400 12.3%	516,100 25.1%	4,720 .2%	0 0%	0 0%
238 Arkansas River at Ralston, Okla.	5,006,000	1,602,200 32.0%	1,183,300 23.6%	859,700 17.2%	1,360,000 27.2%	0 0%	0 0%	0 0%
403 Arkansas River at Van Buren, Ark.	24,682,000	7,234,000 29.3%	14,952,000 60.6%	2,114,000 8.6%	382,800 1.5%	0 0%	0 0%	0 0%
229 Walnut River at Winfield, Kans.	1,013,000	571,700 56.4%	242,100 23.9%	197,200 19.5%	2,450 .2%	0 0%	0 0%	0 0%

Table VII-3 (Continued)

Station No. Stream Location	Total Flow (Ac.-Ft.)	Acre-Feet of Water (and % of Total) of Following Specific Conductance, Micromhos/cm² *						
		0-500	500-1,000	1,000-1,500	1,500-2,500	2,500-5,000	5,000-10,000	10,000-30,000
236 Salt Fork Arkansas River at Tonkawa, Okla.	517,200	101,600 19.6%	41,400 8.0%	13,900 2.7%	47,700 9.2%	272,800 52.8%	39,700 7.7%	0 0%
253 Cimarron River at Perkins, Okla.	984,100	23,200 2.4%	220,700 22.4%	75,200 7.6%	83,800 8.5%	189,600 19.3%	377,800 38.4%	13,900 1.4%
283 Verdigris River near Inola, Okla.	4,027,000	2,490,000 61.8%	1,523,000 37.8%	13,800 .4%	106 0%	0 0%	0 0%	0 0%
392 Canadian River at Whitefield, Okla.	3,383,000	1,459,000 43.1%	1,435,000 42.4%	428,800 12.7%	61,000 1.8%	0 0%	0 0%	0 0%

* Average of all waters below 1,000 micromhos/cm² conductance, when combined, is considered to meet Public Health Service drinking water standards.

** October 1960-September 1961.

*** October 1961-September 1962.

Table VII-4

Red River Basin - Selected Stations
Quantity and Percentage of Water of Various Qualities
(October 1960 - September 1962)

Station No., Stream, and Location	Total Flow Acre-Feet	Acre-Feet of Water (and % of Total) of Following Specific Conductance, Micromhos/cm² *							
		0-500	500-1000	1000-1500	1500-2500	2500-5000	5000-10,000	10,000-30,000	> 30,000
Oct. 1960 - Sept. 1961 (Water Year 1961)									
478-Red River near Brice, Texas	63,000	0 0.0%	0 0.0%	0 0.0%	29,100 46.2%	24,100 38.3%	4,550 7.2%	5,090 8.1%	136 0.2%
481-Salt Fork Red R. nr. Mangum, Okla.	122,400	100 0.1%	51,300 41.8%	14,600 12.0%	36,700 30.0%	19,700 16.1%	15 0.0%	0 0.0%	0 0.0%
490-North Fk. Red R. nr. Headrick, Okla.	427,100	0 0.0%	26,300 6.1%	121,700 28.5%	129,400 30.3%	117,500 27.5%	31,900 7.5%	274 0.1%	0 0.0%
503-Wichita R. at Wichita Falls, Texas	298,500	20,700 6.9%	38,500 12.9%	46,900 15.7%	62,500 20.9%	117,800 39.5%	11,800 4.0%	229 0.1%	0 0.0%
507-Red River near Terral, Oklahoma	1,940,000	0 0.0%	61,300 3.2%	172,700 8.9%	850,400 43.8%	621,100 32.0%	234,600 12.1%	0 0.0%	0 0.0%
508-Red River nr. Gainesville, Texas	2,204,000	0 0.0%	40,700 1.8%	155,100 7.0%	1,057,000 48.0%	682,600 31.0%	268,300 12.2%	0 0.0%	0 0.0%
520-Washita R. nr. Durwood, Oklahoma	819,800	271,400 33.1%	343,300 42.1%	196,300 24.0%	6,830 0.8%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
522-Red River nr. Colbert, Oklahoma	2,941,000	0 0.0%	0 0.0%	0 0.0%	2,935,000 99.8%	6,370 0.2%	0 0.0%	0 0.0%	0 0.0%
529-Red River at Index, Arkansas	7,318,000	1,920,000 26.2%	2,113,000 28.9%	1,502,000 20.5%	1,783,000 24.4%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
750-Red River near Quanah, Texas	204,600	0 0.0%	0 0.0%	687 0.3%	1,750 0.9%	94,200 46.0%	52,300 25.6%	55,600 27.2%	0 0.0%
752-Wichita R. below Lake Kemp, Texas	162,000	0 0.0%	4 0.0%	4 0.0%	28 0.0%	162,000 100.0%	0 0.0%	0 0.0%	0 0.0%
Oct. 1961 - Sept. 1962 (Water Year 1962)									
478-Red River near Brice, Texas	40,300	0 0.0%	0 0.0%	0 0.0%	42 0.1%	22,700 56.3%	15,700 39.0%	1,800 4.5%	27 0.1%
481-Salt Fork Red R. nr. Mangum, Okla.	57,800	273 0.5%	8,030 13.9%	16,800 29.1%	24,200 41.8%	8,500 14.7%	0 0.0%	0 0.0%	0 0.0%
490-North Fk. Red R. nr. Headrick, Okla.	307,100	7,420 2.4%	26,500 8.7%	71,700 23.3%	116,300 37.9%	39,200 12.8%	45,000 14.6%	1,030 0.3%	0 0.0%
503-Wichita R. at Wichita Falls, Texas	116,900	0 0.0%	8,600 7.4%	15,900 13.6%	19,900 17.1%	46,200 39.5%	26,000 22.2%	257 0.2%	0 0.0%
507-Red River near Terral, Oklahoma	1,556,000	0 0.0%	121,100 7.8%	455,200 29.2%	412,100 26.5%	514,800 33.1%	52,300 3.4%	0 0.0%	0 0.0%
508-Red River nr. Gainesville, Texas	1,874,000	0 0.0%	201,900 10.7%	686,200 36.6%	398,500 21.3%	564,400 30.2%	23,000 1.2%	0 0.0%	0 0.0%
520-Washita R. nr. Durwood, Oklahoma	976,800	297,100 30.4%	388,500 39.8%	250,900 25.7%	40,300 4.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
522-Red River nr. Colbert, Oklahoma	3,137,000	0 0.0%	0 0.0%	0 0.0%	3,137,000 100.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
529-Red River at Index, Arkansas	7,912,000	2,299,600 29.1%	2,188,100 27.7%	1,475,300 18.6%	1,949,300 24.6%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
750-Red River near Quanah, Texas	136,100	0 0.0%	0 0.0%	0 0.0%	119 0.1%	24,000 17.6%	68,800 50.6%	41,500 30.5%	1,650 1.2%
752-Wichita R. below Lake Kemp, Texas	84,100	0 0.0%	2 0.0%	4 0.0%	22 0.0%	84,000 99.9%	108 0.1%	0 0.0%	0 0.0%

* Average of all waters below 1000 micromhos/cm² conductance, when combined, is considered to meet Public Health Service drinking water standards.

Table VII-5

Major Natural Sources of Brine

Map* Area No.	Salt Source Area	Identifying Community	Description- Type Emission, Extent, Size	Approximate Concentration of Brine as Cl (mg/l)
	Arkansas River Basin			
II	Big Salt Plains, Okla.	Edith, Okla.	About four-mile stretch of Cimarron River (one mile along Buffalo Creek). Densely encrusted salt plains up to two miles wide. Numerous small springs and seeps (less than 5 gpm). Substantial surface flows of brine at lower end of Area.	190,000
I	Great Salt Plains, Okla.	Cherokee, Okla.	10,000-acre salt flat immediately above Great Salt Plains Reservoir; saturated brine about 1½' below ground surface at edge of salt flat. Brine may flow on surface at edges of reservoir and into reservoir underwater.	190,000
III	Little Salt Plains, Okla.	Buffalo, Okla.	Similar to Area II. Plain about two miles long, and up to one mile wide.	190,000
IV	Salt Creek, Okla.	Southard, Okla.	Numerous small brine springs at base of 300' canyon at upper end of creek.	60,000

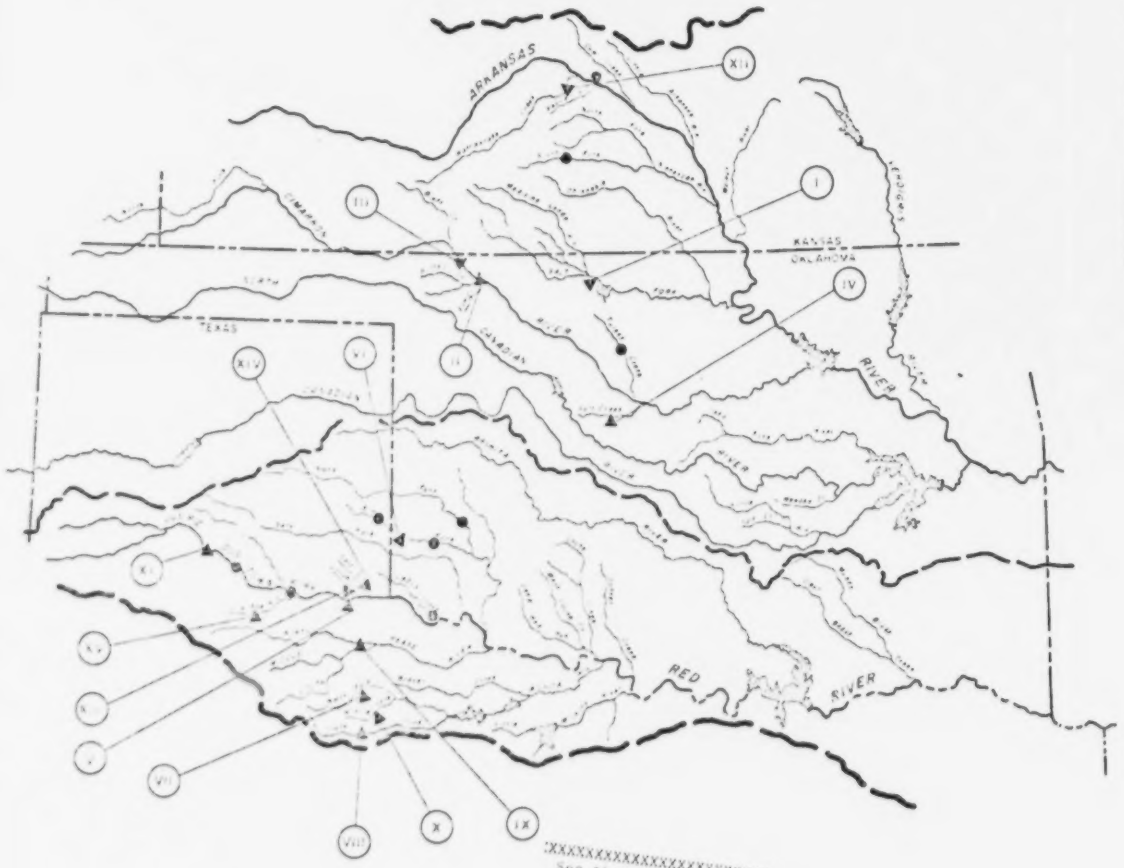
Table VII-5 (Con.)

Map* Area No.	Salt Source Area	Identifying Community	Description- Type Emission, Extent, Size	Approximate Concentration of Brine as Cl (mg/l)
XII	Rattlesnake Creek, Kans.	Raymond, Kansas	Numerous small seeps into two salt water marshes and along bed of Rattlesnake Creek.	11,000
	Red River Basin			
V	Estelline Spring, Texas	Estelline, Texas	Large 5 cfs (3 million gals/day) spring 75' diameter at surface. Flow constant, 1959-62.	25,000
VI	Elm Fork, Okla.	Carl, Okla.	Numerous seeps and small springs near mouths of three canyon streams (tributaries to Elm Fork of Red River) about one mile apart.	190,000
VII	North Fork, Wichita River, Texas	Paducah, Texas	Several large springs, numerous seeps and salt plains, mostly on two-mile stretch above mouth of Salt Creek of N. Wichita River.	20,000
VIII	South Fork, Wichita River, Texas	Guthrie, Texas	Several large springs and numerous seeps along two-mile stretch on S. Wichita River.	4,000-27,000
IX	Middle and North Fork, Pease River, Texas	Childress, Texas	Numerous seeps along two-mile stretches of both North Pease and Middle Pease Rivers.	10,000-20,000

Table VII-5 (Con.)

Map* Area No.	Salt Source Area	Identifying Community	Description- Type Emission, Extent, Size	Approximate Concentration of Brine as Cl (mg/l)
X	Middle Fork, Wichita River, Texas	Paducah, Texas	One large spring and several small seeps along two-mile stretch of Middle Wichita River.	2,000-4,000
XI	Prairie Dog Town Fork, Texas	Brice, Texas	Numerous brine seep areas along Prairie Dog Town Fork of Red River, mostly at mouths of tributary streams.	4,000-32,000
XIII	Jonah Creek, Texas	Childress, Texas	Salt plains and one large and numerous small brine springs in stream bed and along edge of Jonah Creek along a three-mile stretch above mouth.	27,000-40,000
XIV	Salt Creek, Texas	Childress, Texas	Numerous small seeps in stream bed along two-mile stretch above mouth.	30,000
XV	Little Red River, Texas	Turkey, Texas	Numerous small seeps and springs in stream bed at upper end of Little Red River for about one-mile stretch of both North and South branches.	100,000 150,000

*See Figure VII-5



N

VICINITY MAP

SIGNIFICANT * NATURAL BRINE EMISSION AREAS

AREA NO	LOAD - TONS/DAY, AVERAGE		ESTIMATED CONCENTRATED BRINE FLOW **
	As Chloride (Cl)	As Salt (NaCl)	CFS
	(ADD TONNAGE FROM SECOND ACTIVE AREA)		
I	1400	2310	5
II	2950	4960	10
III	600	990	2
IV	220	360	1
V	375	620	1
VI	250	410	1
VII	200	330	2
VIII	200	330	2
IX	350	580	2
X	50	80	1
XI	175	290	2
XII	200	330	2
XIII	450	740	4
XIV	150	250	2
XV	150	250	1

:XXXXXXXXXXXXXXXXXXXXXXXXX>
See the following pages
for greater detail.
:XXXXXXXXXXXXXXXXXXXXXXXXX

SCALE IN MILES

* NINE OTHER SECONDARY SOURCES RELEASE ABOUT 1,060 TONS CHLORIDE/DAY

** COMPUTED FROM LOAD AND BRINE CONCENTRATION

▲ SIGNIFICANT NATURAL BRINE EMISSION AREA

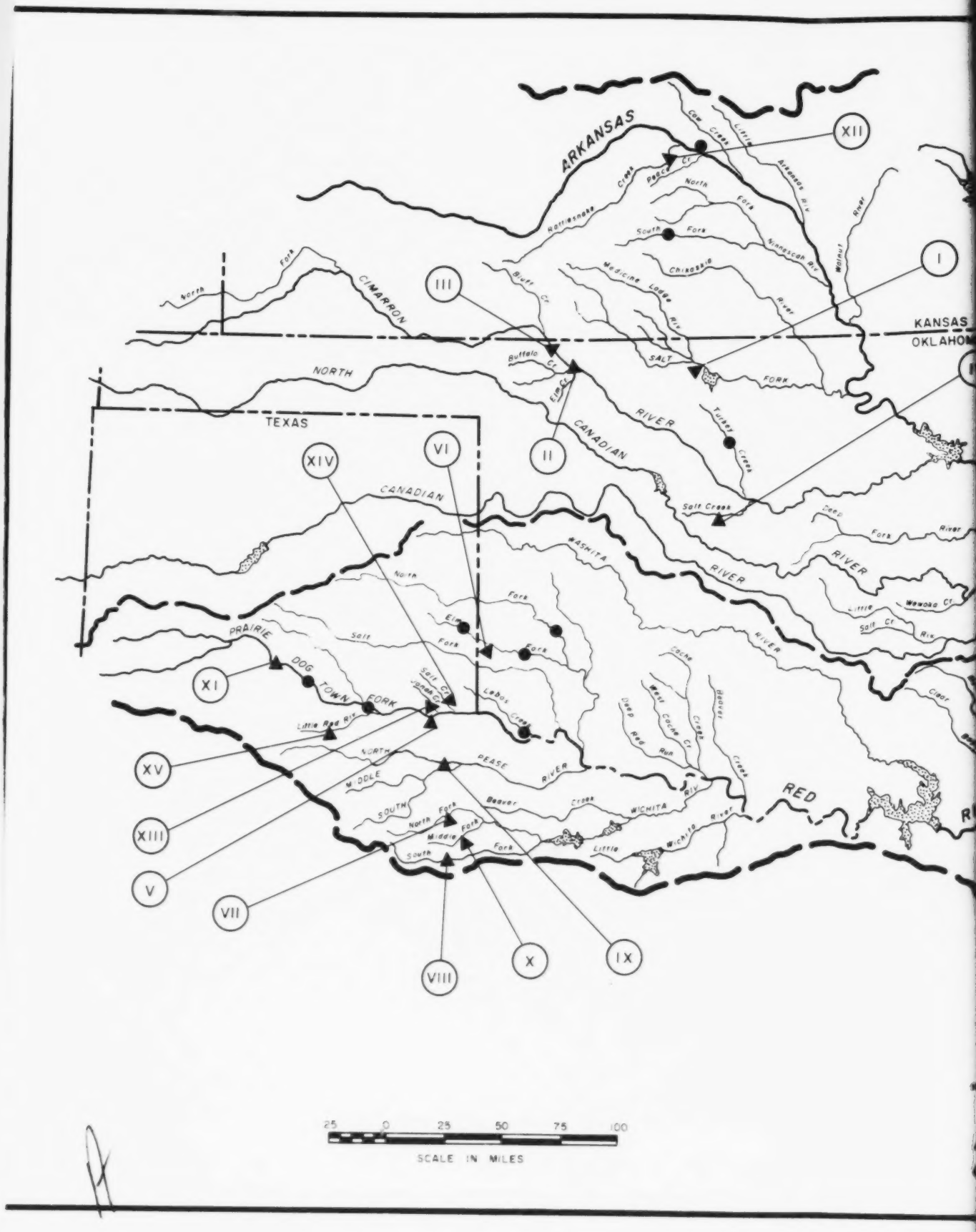
● SECONDARY NATURAL BRINE EMISSION AREA

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

LOCATION OF NATURAL BRINE EMISSIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIGURE VII-5


ARKANSAS
Cow Creek
Little
Arkansas River
Pace Ck.
North
Fork
Rattlesnake
Creek
South
Fork
Winnescah River
Walnut
River
Chikaskia
Medicine Lodge
River
Bluff Ck.
CIMARRON
North
Fork
KANSAS
OKLAHOM
SALT
FORK
Buffalo
Ck.
Elbow Ck.
NORTH
TEXAS
RIVER
CANADIAN
Turkey
Creek
Salt Creek
CANADIAN
Deep
Fork
River
WASHITA
RIVER
Little
Washita Ck.
Salt Ck.
Rive
North
Fork
Elm
Fork
Fork
PRAIRIE
DOG
TOWN
FORK
Salt
Fork
Salt Ck.
Creek
Labos
Creek
Cache
Creek
West Cache Ck.
Deep Red
Run
Beaver
Creek
RIVER
Clear
Little Red Riv.
NORTH
MIDDLE
SOUTH
PEASE
RIVER
Beaver
Creek
WICHITA
RIV.
RED
North
Fork
Middle
Fork
South
Fork
Little
Wichita
River
I
II
III
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
25 0 25 50 75 100
SCALE IN MILES

VICINITY MAP

SIGNIFICANT * NATURAL BR

AREA NO	LOAD-TONS/DAY, A	
	As Chloride	As S
	Load computed from Water Years	Sh
I	1400	
II	2950	
III	600	
IV	220	
V	375	
VI	250	
VII	200	
VIII	200	
IX	350	
X	50	
XI	175	
XII	200	
XIII	450	
XIV	150	
XV	150	

* NINE OTHER SECONDARY SOURCES RELEASE ABOUT 1,060 TONS CHLORIDE/DAY

** COMPUTED FROM LOAD AND BRINE CONCENTRATION

100

▲ SIGNIFICANT NATURAL BRINE EMISSION AREA

● SECONDARY NATURAL BRINE EMISSION AREA

U.S.

B

VICINITY MAP

SIGNIFICANT * NATURAL BRINE EMISSION AREAS

AREA NO	LOAD - TONS/DAY, AVERAGE (Load computed from 1961-62 Water Years Study)		ESTIMATED CONCENTRATED BRINE FLOW ** (CFS)
	As Chloride	As Salt (NaCl)	
I	1400	2310	5
II	2950	4960	10
III	600	990	2
IV	220	360	1
V	375	620	5
VI	250	410	1
VII	200	330	2
VIII	200	330	2
IX	350	580	2
X	50	80	1
XI	175	290	2
XII	200	330	2
XIII	450	740	4
XIV	150	250	2
XV	150	250	1

NINE OTHER SECONDARY SOURCES RELEASE ABOUT 1,060 TONS CHLORIDE/DAY

COMPUTED FROM LOAD AND BRINE CONCENTRATION

SIGNIFICANT NATURAL BRINE EMISSION AREA

SECONDARY NATURAL BRINE EMISSION AREA

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

LOCATION OF NATURAL BRINE EMISSIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VII-5

The emission rate of many of the natural brines was difficult to determine or predict. Some natural brine flows appear to vary directly with the rainfall and stream variations. Large amounts of solid salt have accumulated in the vicinity of and below these sources. Examples are the 10,000-acre Great Salt Plains (Area I) in Oklahoma; the broad, 4-mile long salt flats of the Big Salt Plains in the Cimarron River streambed in Oklahoma (Area II); and the 25-mile salt plain which develops on the Little Red River in Texas (Area XV) during dry weather.

Table VII-6 lists seven additional natural mineral pollut sources that were found from load balances of the monitoring network results and from conferences with State officials. These sources are classified as secondary because their brines do not have an excessively degrading effect. Two additional presumed natural sources are shown in Table VII-6. The total salt loads of these nine pollution sources, as sodium chloride, are 800 tons per day in the Arkansas River basin and 940 tons per day in the Red River system. Several of these sources, particularly those in the Arkansas near Great Bend, Kansas; the Ninnescah near Haven, Kansas; and above and below the three canyon streams, tributary to Elm Fork of Red River (Area VI) will be investigated in more detail.

Although further study may add other pollution sources to this category, it is believed that the fifteen primary sources are the most significant and that their control or elimination will provide maximum water quality improvement. If, for example, the five major salt sources in the Arkansas River are eliminated, about 8,950 tons of salt per day will no longer be discharged into the river. At an average annual streamflow of 6,700 cfs at Tulsa, Oklahoma, chloride concentrations will be reduced by 320 mg/l, leaving about 150 mg/l of chloride from other sources. In the Red River basin, elimination of all ten primary salt sources will reduce the salt loading by 3,870 tons per day and lower the chloride concentration at average flows by 150 mg/l, leaving 200 mg/l from other sources.

Geological studies of the Ground Water Branch of the Geological Survey show that these salt waters are relatively young and that the phenomenon of fresh water percolating downward through formations containing salt and its eventual reappearance as brine occurs within an area of a 10-mile radius or less. During dry weather the brines may evaporate or flow underground shortly after they reach the streambeds. Figure VII-6 is an idealized sketch of the brine generation and emission phenomenon, based upon the Geological Survey findings. 16/

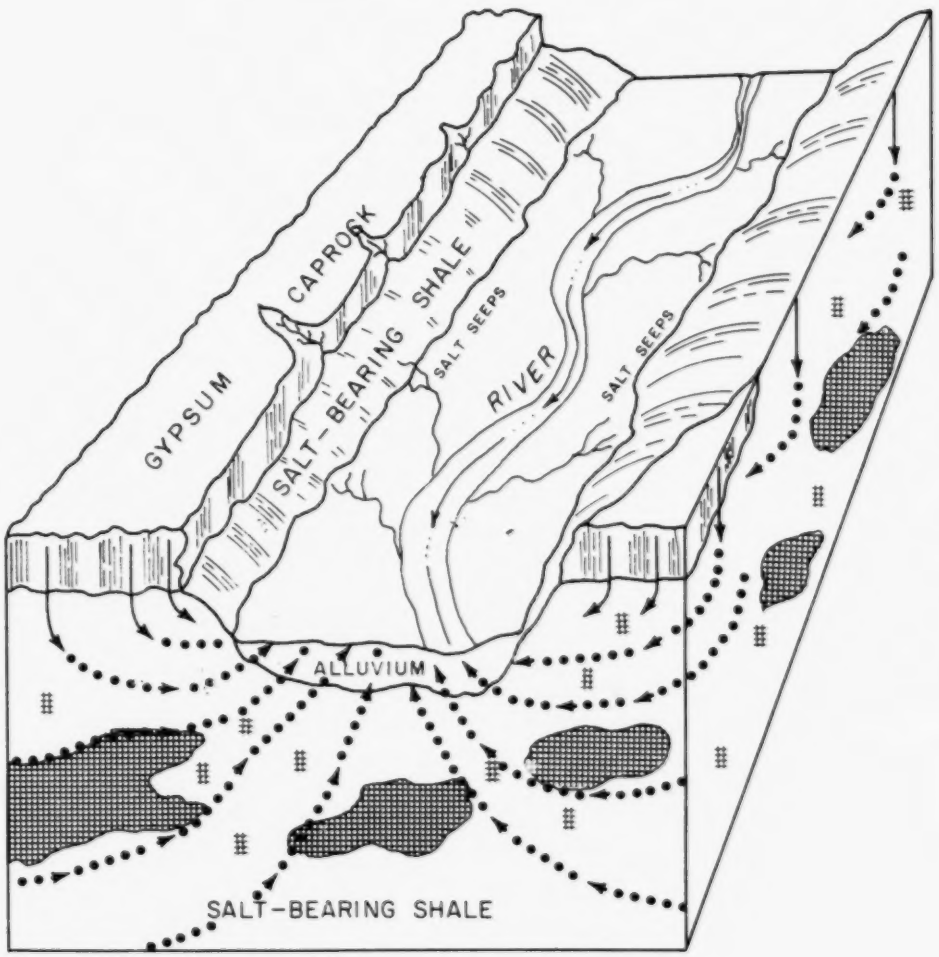
Table VII-6

Secondary Natural Brine Sources

	General Location	Estimated Salt Load Tons NaCl/Day
Arkansas River	Ninnescah River (Kansas)	350
	Turkey Creek (Cimarron River, Okla.)	50
	*Arkansas River and Tributaries Between Great Bend & Hutchinson	400
	Total	800
Red River	Red River and Tributaries Between Area XI and Estelline, Texas	80
	Lebos Creek Downstream from Eldorado, Okla.	80
	Elm Fork of Red River, Immediately above Area VI	160
	**Elm Fork of Red River and Tributaries Downstream from Area VI	400
	Boggy Creek of North Fork of Red River	20
	*Below Area XI (Additional)	200
	Total	940

* Presumed source--Located (general) and estimated on basis of stream monitoring network load balance.

** 100 T/D secondary and 300 T/D presumed.



LEGEND:

BEDDED SALT

DISSEMINATED SALT

FRESH GROUND WATER

SALTY GROUND WATER

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

IDEALIZED SKETCH OF GROUND WATER MOVEMENT AND ACTION ON SALT-BEARING FORMATIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VII-6

Calcium and sulfate are added to the streams by the passage of water over and through the large surface and subsurface deposits of gypsum (calcium sulfate) in the area. Figure V-1 shows the locations of surface outcrops of gypsum and of the subsurface deposits of salt.

In general, in these basins, sulfate concentrations are lower than chlorides and are less objectionable. Methods similar to those for chloride control cannot now be suggested for appreciable sulfate reduction and should be the subject of further research. Estimates are that procedures which reduce natural and manmade mineral pollution will provide at least a 5 percent reduction in sulfates. The final sulfate concentrations will place no serious limitations on water use.

Manmade Brine Sources

Brine from oil and gas production accounts for over 90 percent of the manmade load. Table VII-7 shows the magnitude of this waste disposal problem, and Figure IV-3 shows the area covered by this industry.

Table VII-7

Oil Brine Production and Reinjection
Arkansas and Red River Basins

	Oklahoma	Kansas	Texas
Oil Production (1960) (mil. bbls.)	200	100	150
Total Brine Production/Day* (mil. bbls.)	1.5e	2.54	0.6e
Estimated Chloride in Brine* (tons/day)	50,000e	36,700	25,000e
Brine to Pit or Direct to Stream* (bbls./day)	**	3,000	**
(tons/day)	**	120	**
Percent Reinjected*	95+	99.7	95+

e Estimated.
* Information obtained from State agencies.
** Information not available.

The portions of Oklahoma, Kansas, and Texas in the Arkansas-Red River basins produce about 17 percent of the United States oil. For each barrel of oil, as much as 100 barrels of salt water may be produced with concentrations ranging from a few thousand milligrams per liter to 200,000 mg/l of chloride. 17/ The potential load is enormous and the dedicated work of State and local agencies together with the cooperation of petroleum producers has resulted in the reinjection of an estimated 95 percent of the oilfield brines. However, the residual 5 percent is troublesome and should be brought under control.

Streams such as the Verdigris River in Kansas and Oklahoma, Walnut River in Kansas, and Little Wichita in Texas appear to contain only manmade brines. During this study, as shown on Figures VII-1 and VII-2, the average dissolved solids concentrations in these streams were less than 500 mg/l.

Other industrial sources of salt waste (other than gas and oil production) are four salt plants and a chemical plant which uses underground salt. The salt load from these industries is estimated as 70 tons per day average (1963) by the Kansas Board of Health.

Liquefied petroleum gas storage operations are a potential source of salt water. These storage caverns are leached in salt beds and the saturated brine is used to displace or remove the liquefied petroleum gas. Losses during construction and operation are reported to be minor.

Many activities produce salt as a water-borne waste. Salt used for domestic purposes and in the regeneration of water softeners is carried out in sewage, but it is a minor portion of the total salt load. The total salt waste load from municipal and domestic activities is estimated to average less than 3 percent of the total salt load measured at the lowermost stations.

It was recently estimated that more than 1,000,000 tons of livestock salt was used in the United States. With 8.1 percent of the United States livestock pastured in these basins, it is assumed that a portion of this salt is washed off into basin streams.

VIII. WATER QUALITY OBJECTIVES

Advance planning for water quality control in the Arkansas-Red River basins, including cost estimates, depends on the extent to which the mineral pollutants in these streams are to be eliminated. Water quality objectives are needed which are realistic in terms of needs and capable of fulfillment at a reasonable cost. Because sodium chloride is the major mineral pollutant, chloride concentration has been selected as an indication of water quality in these basins. Elimination or reduction of the sources of chloride pollution will also effect a reduction in the amount of sulfate and dissolved solids in the basins' streams.

According to the Public Health Service Drinking Water Standards, 1962, in use by State agencies of the Arkansas-Red River basins, the presence in drinking water of either chlorides or sulfates in excess of 250 mg/l is unacceptable, if other more suitable supplies are or can be made available. 18/ However, this standard does not meet the requirements of all the water uses shown in Table VIII-1. The quantities shown are those at which impairment has been found and a lower concentration is usually desirable. A chloride concentration of 100 mg/l is considered as desirable in meeting the needs of most users listed in Table VIII-1.

Table VIII-1

Chloride Concentration-Use Spectrum

Use	Concentration (mg/l)
Stock and Wildlife	1,500
Food Canning and Freezing	760
Domestic Water Supply	250
Carbonated Beverages	250
Food Equipment Washing	250
Irrigation 19/	250
Paper Mfg., Kraft pulp	200
Steel Making	175
Textile Process	100
Brewing	80
Paper Mfg., soda pulp	75
Paper Mfg., ground wood pulp	75
Dairy Industry	30

Source: California Water Pollution Control Board 20/

Local and State officials have indicated that mineral concentrations should be reduced as much as possible to afford maximum development opportunities to industries requiring high quality water. The ultimate objective is a reduction in the salt loads of the entire river systems. This would encourage economic development uniformly throughout the basins, other factors being equal.

IX. PROPOSALS FOR THE CONTROL OF MINERAL POLLUTION

Natural brine emissions located and defined in this report, together with oilfield brines, contribute an estimated 95 percent of the mineral pollution in the Arkansas-Red River basins. It is estimated that this pollution is carried in considerably less than 1 percent of the average flow of the affected streams shown on Figure IX-1. Control of natural and oilfield brine pollution will be required to achieve the chloride concentration objective of 100 mg/l or less in the stream reaches where use is expected to develop.

Natural Mineral Pollution Reduction

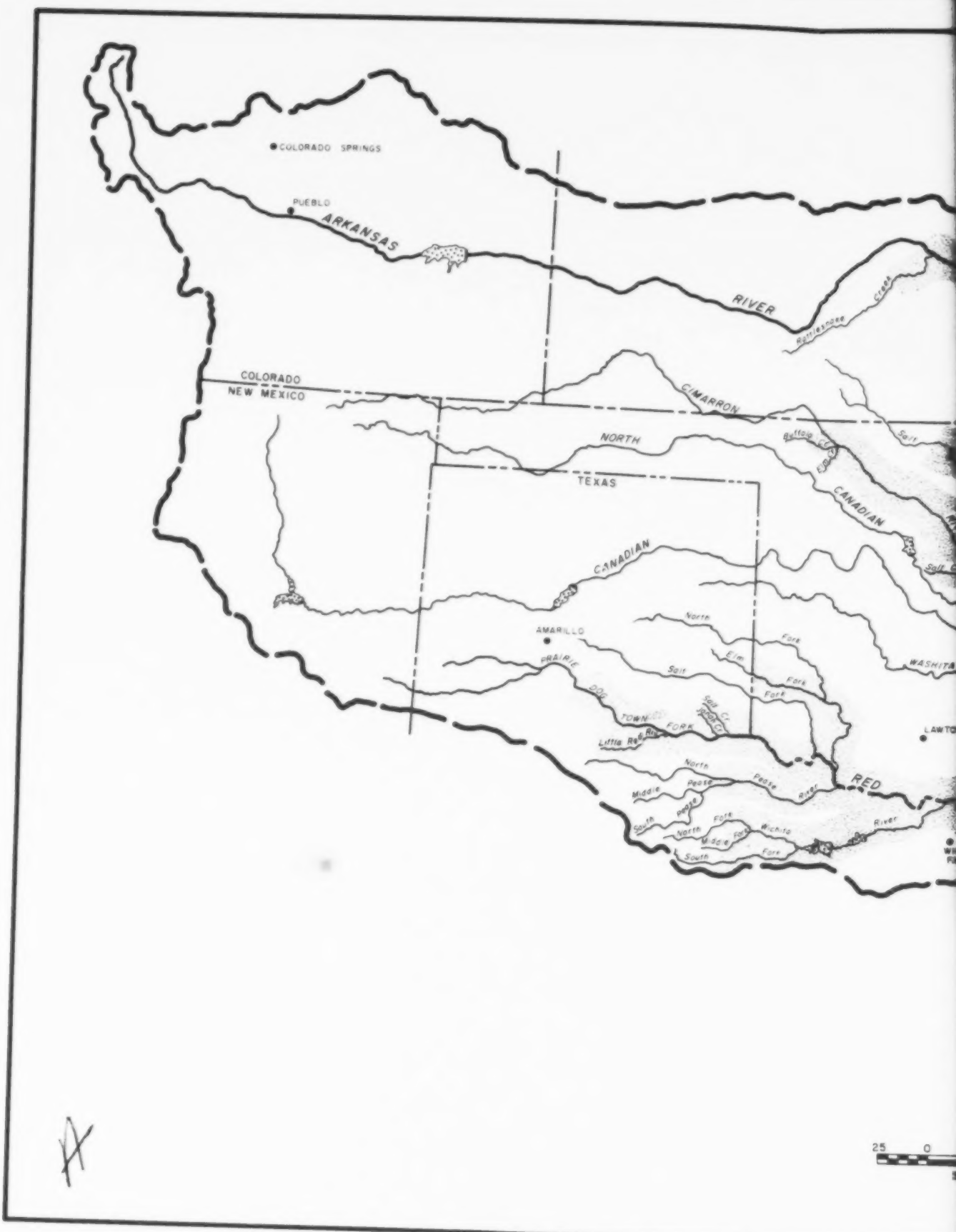
Numerous procedures have bee.. suggested for the elimination or reduction of natural brine flows reaching the streams in these basins involving engineering works such as dams, dikes, storage basins, canals, and pumping systems for the collection, storage, suppression, and transmission of the natural brines. Although engineering and design practices are well advanced for water resource development projects, the control of large volumes of brines is unique and untried.

The Corps of Engineers is studying brine control methods and field testing one of those proposed. The following broadly classified proposed methods (either alone or in combination) will be studied.

Subsurface Disposal of Brines

Most brines from oil and gas production in these basins are currently reinjected into the formations from which the oil and gas have been extracted. Similar subsurface disposal of natural brines may be possible; if suitable geological formations underlie, or are not too distant from, natural brine sources, and the volume of the brines is not too great, such disposal may be satisfactory.

The University of Oklahoma conducted a preliminary study of the potential for subsurface disposal of natural brines in both basins. It was concluded that this method offers promise; receptive subsurface strata of large capacity are available and disposal costs seem reasonable. Table IX-1 summarizes the pertinent data and costs estimated for injection equipment, operation, well drilling, and the capacity of subsurface formations. The actual costs of this method of disposal can only be determined by field tests at each site. The disposal areas considered are within a 20-mile radius of the salt source. Although the study was limited to shallow strata, about 5,000 feet deep, the desirability of investigating deeper strata in the southwestern portions of the basins was recognized.[21/]


COLORADO SPRINGS
PUEBLO
ARKANSAS
RIVER
Rattlesnake Creek
COLORADO
NEW MEXICO
CIMARRON
NORTH
TEXAS
CANADIAN
CANADIAN
AMARILLO
PRAIRIE DOG TOWN FORK
Little Red R.
North Fork
Elm Fork
Salt Fork
WASHITA
LAWTO
RED
North Pease River
Middle Pease
South Pease
North Fork
Middle Fork
South Fork
Wichita River
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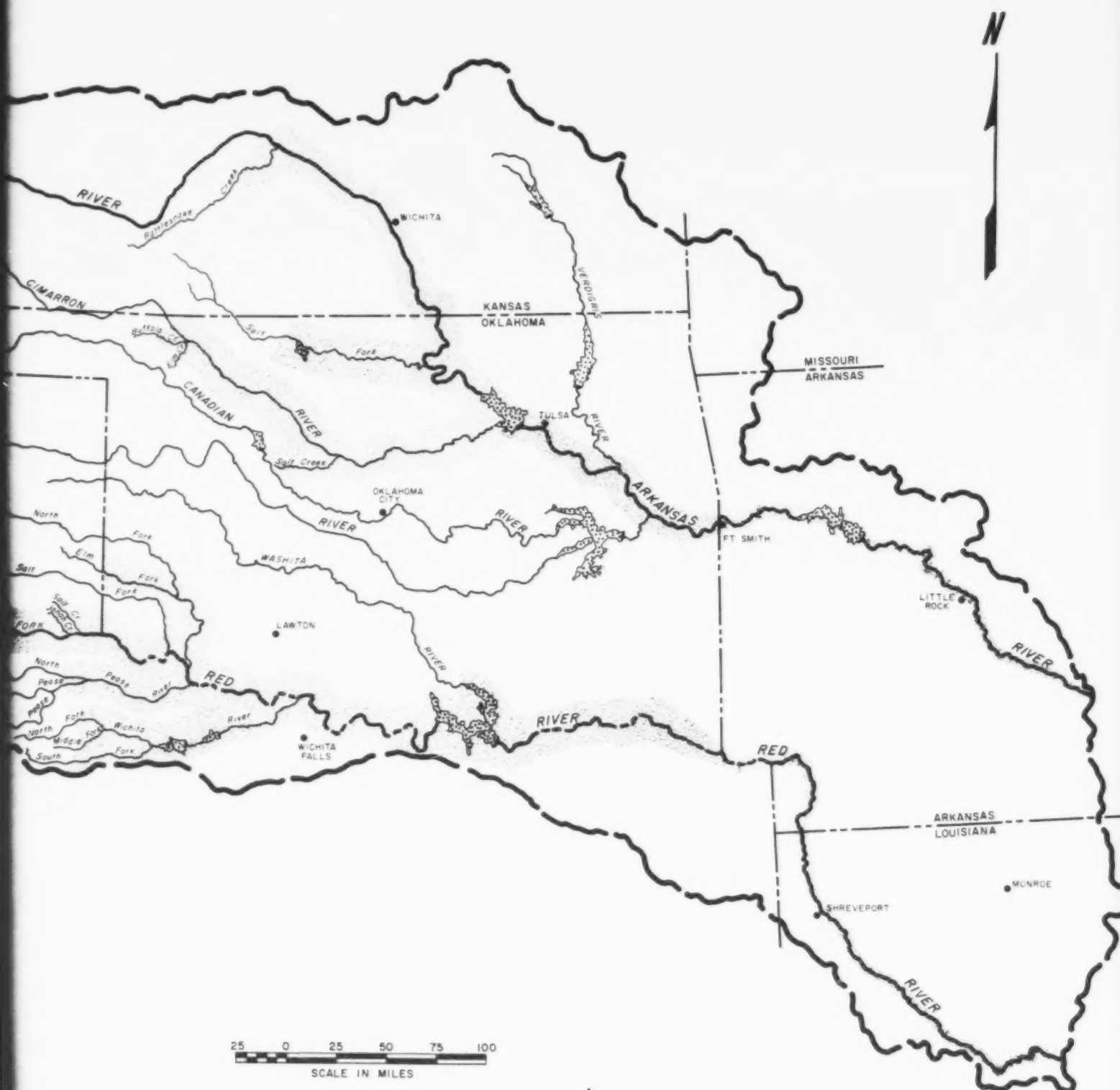
N
RIVER
Rattlesnake Creek
WICHITA
CIMARRON
KANSAS
OKLAHOMA
Salt Fork
Red Fork
CANADIAN
RIVER
Salt Creek
VERDIGRIS
RIVER
MISSOURI
ARKANSAS
TULSA
OKLAHOMA CITY
ARKANSAS
RIVER
FT. SMITH
North Fork
Elm Fork
Salt Fork
WASHITA
RIVER
LITTLE ROCK
RIVER
Salt Cr.
Rock Cr.
FORK
LAWTON
RED
North Pease
Pease River
Pease
North Fork
Middle Fork
South Fork
Wichita River
WICHITA FALLS
RIVER
RED
RIVER
ARKANSAS
LOUISIANA
MONROE
SHREVEPORT
RIVER
25 0 25 50 75 100
SCALE IN MILES

VICINITY MAP

N

MISSOURI
ARKANSAS

RIVER

ARKANSAS

FT SMITH

LITTLE ROCK

RIVER

RED

ARKANSAS
LOUISIANA

MONROE

SHREVEPORT

RIVER

LEGEND

STREAM REACH DEGRADED BY NATURAL BRINE EMISSIONS

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

AFFECTED STREAMS

U S DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE IX-1

Table IX-1

Natural Brine Disposal Cost Estimates* By Subsurface Injection
(Includes all capital, amortization, and operation costs)

Area and Brine Source	Brine Volume (cfs)	Chloride tons/day	No. of Dis-posal Wells	Years Storage (est.)	Cost per mil. gal.	Cost per bbl. (42 gal)	Chloride Cost per ton	Total Annual Cost Thousand $
I - Great Salt Plains	5	1,400	13	80-160	$445	1.8¢	$0.90-$1.81	$525-$1,050
II & III - Big Salt Plains and Little Salt Plains	12	3,600	6	200-300	448	1.8	0.22-0.35	321-512
IV - Salt Creek of Cimarron River	1	225	1	2,700	426	1.7	1.38	106
V - Estelline Spring	5	375	5	750	533	2.2	3.97	507
VI - Elm Fork Springs	1	250	4	1,000	415	1.7	0.90	98.4
VII, IX, and X - North Wichita River, Middle Wichita River and Pease River	5	600	4	1,000	550	2.3	4.77	522
VIII - South Wichita River	2	200	4	250	502	2.1	8.70	477

Source: University of Oklahoma, Study for Public Health Service 21/

The James A. Lewis Engineering, Inc., of Dallas, made a preliminary investigation for the Public Health Service of the potential for subsurface disposal of natural brines into deep formations in the upper Red River basin. Attention was directed mainly to the Arbuckle (or Ellenburger) formation underlying portions of Kansas and northern Oklahoma which has great receptive capacity. It was concluded that this method has promise for some areas but that more basin information is needed. 22/

Permanent Storage-Retention of Natural Brines

Brines can be collected and retained in off-channel storage, as in the case of the Great Salt Plains. Here, fresh water upstream from the plains could be diverted around the plains to the downstream side of the reservoir. Brines would be stored in the Great Salt Plains Reservoir and an alternate means of flood control would have to be found. It is estimated that the reservoir with minor modifications has a brine storage capacity of 100 years or more at the present rate of brine emission. The rate of brine emission may well lessen as the depth of stored brine increases, thus increasing the hydrostatic head.

Elimination or Reduction of Fresh Recharge Waters To Subsurface Salt Deposits

Part of the rainfall goes into the ground and percolates slowly downward through porous rocks and soils. When this underground water comes in contact with salt deposits, part of the salt is dissolved and forms a concentrated brine which may appear as a salt spring or seep at the ground surface. If the flow of fresh water can be eliminated, or its direction of flow changed so that it no longer dissolves salt or has sufficient head to reach the ground surface, this source of brine can be controlled.

Elimination or Reduction of Brine Flows By Hydrostatic Pressure

Natural brine springs are hydrologic phenomena which appear to have a low static head or driving force. Inundation (or plugging of large single springs) may impose enough back pressure to stop or reduce the brine flow. The Corps of Engineers is currently conducting two tests to ascertain the practicability of this method and to obtain basic data on the effects of such inundations on the hydrologic environment. The tests will include a dike around Estelline Spring (Area V) to impose a static head of about 6 feet on the spring, and the imposition of a 6- to 10-foot hydrostatic head on a large spring on the South Wichita River (Area VIII).

Transportation to Nondamaging Disposal Site

Accumulated stored brines, as well as brines at each source, may be collected and transported with wastes by pipelines or canal to areas with large assimilation capacity such as the Gulf of Mexico.

Utilization of Salt

Answers from inquiries to the Chlorine Institute, Salt Institute, and other large individual salt producers and users indicate that increased utilization of salt is only a remote possibility. An increase in present-day demands and/or process may stimulate removal, but the amount extracted will be only a small portion of that discharged.

About 3,000 tons of salt per day are produced from underground deposits, mostly in the Hutchinson area in Kansas. It may be feasible to replace this salt with natural brine from Big Salt Plains (Area II) and Little Salt Plains (Area III) about 120 miles away on the Cimarron River in Oklahoma. The collection system and pipeline to the existing salt works could be constructed and operated by the pollution abatement agency.

The solid salt from these sources is similar in quality to that produced in the Hutchinson salt plants where the salt is about 97 percent NaCl, about 2.5 percent $CaSO_4$, and the remainder magnesium, chlorides, sulfates, and inerts. Salt from the Great Salt Plains has about the same analysis; weaker brines from other areas contain up to 10 percent $CaSO_4$.

Alternate Supplies and Blending

Sufficiently improved quality may be realized by transferring and blending high quality waters from the eastern part of the basins with those of high mineral content in the central basins. If eastern waters are available for transfer at an early date, a blending plan would increase the total volume of usable water.

Abatement Program for Natural Salt Pollution

Based on preliminary findings, the greatest potential for improvement in water quality lies in effective control of natural salt sources as follows:

1. Sources on the three tributaries of the Wichita River (shown as Areas VII, VIII, and X on Figure VII-5).

2. The Big and Little Salt Plains on the Cimarron River (shown as Areas II and III on Figure VII-5).

3. The Great Salt Plains on the Salt Fork of the Arkansas River (shown as Area I on Figure VII-5).

4. Sources on the Elm Fork of the North Fork of the Red River (shown as Area VI on Figure VII-5).

5. Estelline Spring (shown as Area V on Figure VII-5).

6. Jonah Creek (shown as Area XIII on Figure VII-5).

Criteria used for evaluating the effectiveness of controlling the sources in the order of preference are (1) the urgency of water needs, (2) volume of water improved, and (3) the degree of improvement possible by control of a single source. The larger areas to benefit by this schedule include Wichita Falls, Denison, and Dallas-Fort Worth, Texas; Shreveport and Alexandria, Louisiana; and Tulsa and Oklahoma City, Oklahoma.

State Water Pollution Control Programs

All the States in these basins have pollution control legislation and administration programs (including oil and gas brines) to control water pollution. In general, the interest and sometimes the legal authority are divided among several State agencies which have a direct interest either in the quality of the water, in the development of the water resources, or in the development and control of an industry whose waste material may degrade the water. In all of these States, there are voluntary and/or legally authorized cooperation and coordinated programs by the agencies involved. Legislative authority in all of the basin States appears adequate.

The improvement and maintenance of satisfactory water quality for maximum usage throughout these basins will require abatement and control of both manmade and natural brines. Suggested pollution control program goals, by State and subbasin areas, are shown in Table IX-2.

Table IX-2

Suggested Salt Load Reduction Program
In Arkansas and Red Rivers
(exclusive of primary and
secondary salt sources)

State and Basin	Subbasin and Area	Present (1961-1962) Salt Load*	Load Reduction*	Suggested Maximum Permissible Load After Control Program*
Kansas				
Arkansas River	Grand Neosho River	165	65	100
	Verdigris River	330	230	100
	Walnut River	455	355	100
	Arkansas River & Tributaries - Great Bend to Arkansas City	850	600	250
Oklahoma				
Arkansas River	Salt Fork of Arkansas River	350	250	100
	Cimarron River	575	425	150
	Verdigris River	1,330	1,030	300
	Canadian River	2,360	2,060	300
	Arkansas River - Arkansas City, Kansas to Tulsa, Oklahoma	450	300	150
	Arkansas River - Tulsa to Van Buren, Arkansas	845	645	200
Red River	Washita River	265	215	50
	Red River above Lake Texoma	520	470	50
Texas				
Arkansas River	Canadian River	320	270	50
Red River	Wichita River	360	310	50
	Beaver Creek (Wichita River)	130	105	25
	Red River and Tributaries above Lake Texoma	1,360	1,060	300

* Tons NaCl/day.

X. ECONOMIC ANALYSIS AND BENEFITS

Four factors are involved in the future economic growth prospects of the Arkansas-Red River basins study area. These factors are (1) the condition of the national economy; (2) the oil and gas and other natural resource situation; (3) the geographic location of the basin; and (4) the development of the water resources of the two large river systems.

The condition of the national economy is best indicated by its growth rate as measured by population, employment, and gross national product. Present indications are that the population of the Nation will reach 502 million by 2020, an increase of 178 percent; employment will reach 197 million, an increase of 186 percent; and the gross national product will reach $4.5 trillion, an increase of 778 percent.* These expectations indicate a thriving national economy in which the Arkansas-Red River basins will participate. That is, the future prospects of the basins are closely related to national conditions.

Petroleum and natural gas account for 69 percent of the Nation's energy requirements and 67 percent of the Nation's value of mineral fuel. Their potential for the growing petrochemical industry is increasing. In the light of the above factors, the significance of oil and gas in the national economy can hardly be overstated.

The Arkansas-Red River basins study area produced approximately one-fourth of the Nation's oil and gas in 1960. At the same time, much of the petroleum and natural gas produced in the study area was marketed and refined in other regions. 9-1 1/

Oil and gas production in the future is expected to increase enough to hold its place in the national demand pattern for fuel increases to provide feedstock for the petrochemical industry. Petrochemical production in the study area is expected to increase more than 600 percent by 2020.

Future years should show more in-basin processing of locally produced gas and oil. This increase would be attributable to expected low cost navigation transportation and increasing market size in the Midwest. These factors will make the area more competitive and stimulate regional growth in these products.

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* These growth indicators are based on projections of the Economic Task Group of the AD HOC Water Resources Council Staff.

Pulp and paper production of the basin, though of much lesser significance than oil and gas, should increase in volume and percentage of national totals for reasons similar to the oil and gas situation. The effect will be to increase production about $3\frac{1}{2}$ times.

Agriculture in the study area will continue to increase its output in response to regional and national demands for its products. This increase in production will be associated with additional gains in agricultural productivity. By 2020, the study area should be able to triple its output using half the number of workers employed in 1960. Associated with this increased agricultural production will be the need for equipment and fertilizer. Based on agricultural output and expected national and regional population growth, output from the food and kindred products industry is expected to increase about threefold by 2020.

The geographic location of the basins constituted a considerable handicap early in the century since the major concentrations of population and economic activity were far distant. This locational handicap has been greatly reduced by improved transportation manifested by the highway and air transportation routes as well as by the railroad network of the study area. Continued improvement can be expected in the highways and air facilities. The major improvement in the locational situation, however, arises from the southward and westward trend of the national center of population. The center is now at Salem, Marion County, Illinois, about 50 miles east of St. Louis, a shift of 45 miles westward since 1950. This shift and its expected continuance is contributing to the growth of population and markets in the basins, particularly of the large urban and metropolitan areas. The shift is also influencing the size of large population centers in proximity to the region, especially in proportion to the rest of the Nation. Much of this new and expected growth is within 1-day's trucking or rail distance from basin centers. Therefore, industrial operations seeking a production and distribution base relatively nearby these new markets of the northern and southern Midwest will look more favorably than in the past on the Arkansas-Red River basins for sites.

The fourth factor influencing the growth of the basin involves the two river systems themselves. That is, the two major rivers and their tributaries represent an asset in a current condition of less than optimum development. The rivers can be altered in their performance and use to facilitate or enhance economic activities and to provide essential services and benefits. That is, the river systems can be managed to serve specifically determined purposes in accord with a systematic appraisal of their usefulness. A considerable effort in this regard has already been made as manifested by various flood control structures and reservoirs throughout the area.

Also an active pollution control program is underway among the States with Federal participation and assistance. Plans for navigation and further flood control and multiple-purpose structures also indicate acceptance of the objective of major development and management of this river system's asset.

As significant as these efforts are for the future growth of the region, the development and management of the water quality aspects of these river systems on a comprehensive basis are necessary to assure enhancement of their potential.

At this point in the study, only approximations have been made of the future growth in the basins economy. These approximations are shown as population and labor force projections in Table X-1.

Table X-1

Labor Force and Population Projections for the Study Area--1960 and 2020

Major Industry Group	1960 Number*	1960 Percent	2020 Number*	2020 Percent
Agriculture**	311	9	150	1
Mining	90	3	250	3
Manufacturing	567	17	1,900	20
All Other Employed	2,256	67	6,750	72
Unemployed	144	4	370	4
Total Labor Force	3,368	100	9,420	100
Population	9,335		24,470	

* Thousands of people.
** Includes a small number (less than 1 percent) employed by Forestry and Fisheries.

The water requirements for the several components of the future study area economy are shown in Table X-2.

Table X-2

Total Water Requirements* for the Arkansas-Red River Basins Study Area, 2020 and 2070
(1,000 acre-feet annually)

	Red River Basin and Adjoining Areas	Arkansas River Basin and Adjoining Areas	Total
2020			
Municipal & Industrial**	2,511	1,768	4,279
Irrigation	121	200	321
Total	2,632	1,968	4,600
2070			
Municipal & Industrial**	4,900	3,550	8,450
Irrigation	121	200	321
Total	5,021	3,750	8,771

*Includes current sources of supply.
**Industrial requirement includes cooling water.

If the water quality of the two river systems is improved sufficiently to meet these water requirements, the average annual value of the benefits will be $9,177,000 between 1970 and 2020 and $13,080,000 between 1970 and 2070. Table X-3 indicates the distribution of the value of the benefits among uses for the two river basins.

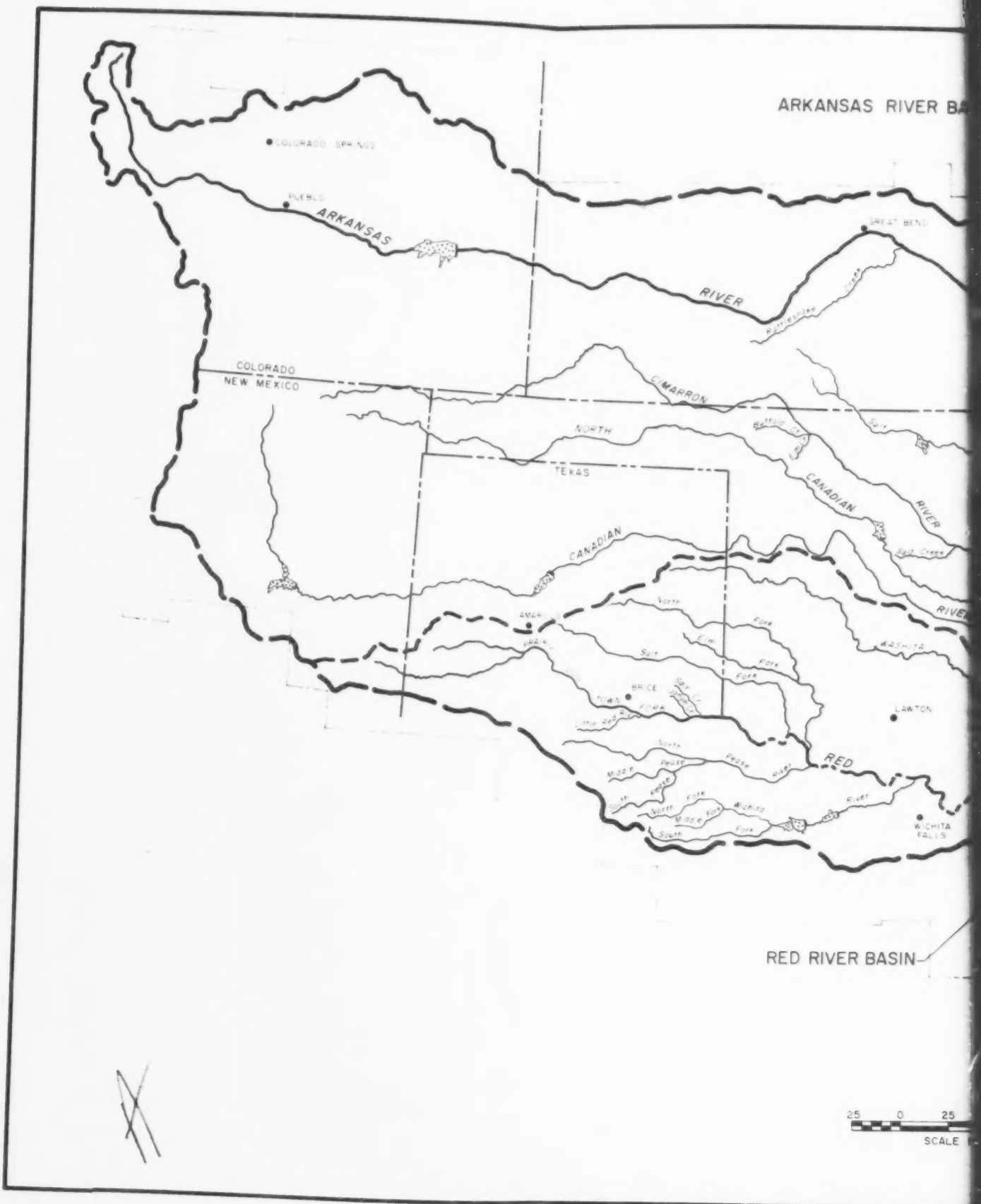
Further study will reveal more clearly the years in which, and the probable location of the areas from which, the water requirements will arise and the stretches of the rivers or their tributaries which must be developed or improved to meet the requirements.

This study should consider information on the cost and effectiveness of natural brine control measures as it becomes available from the Corps of Engineers. Consideration of alternative measures will also require further study. Stress should be placed on areas of urgent water need and on possible control measures suitable for first attention.

Table X-3

Summary of the Value of Benefits - Improvement in Water Quality
Arkansas-Red River Basins Study Area

	Average Annual Value (1970 Worth)					
	1970 to 2020			1970 to 2070		
	Municipal and Industrial	Irrigation	Total	Municipal and Industrial	Irrigation	Total
Red River Basin and Adjoining Areas	6,490,000	106,000	6,596,000	8,645,000	168,000	8,813,000
Arkansas River Basin and Adjoining Areas	2,423,000	158,000	2,581,000	4,016,000	251,000	4,267,000
Total	8,913,000	264,000	9,177,000	12,661,000	419,000	13,080,000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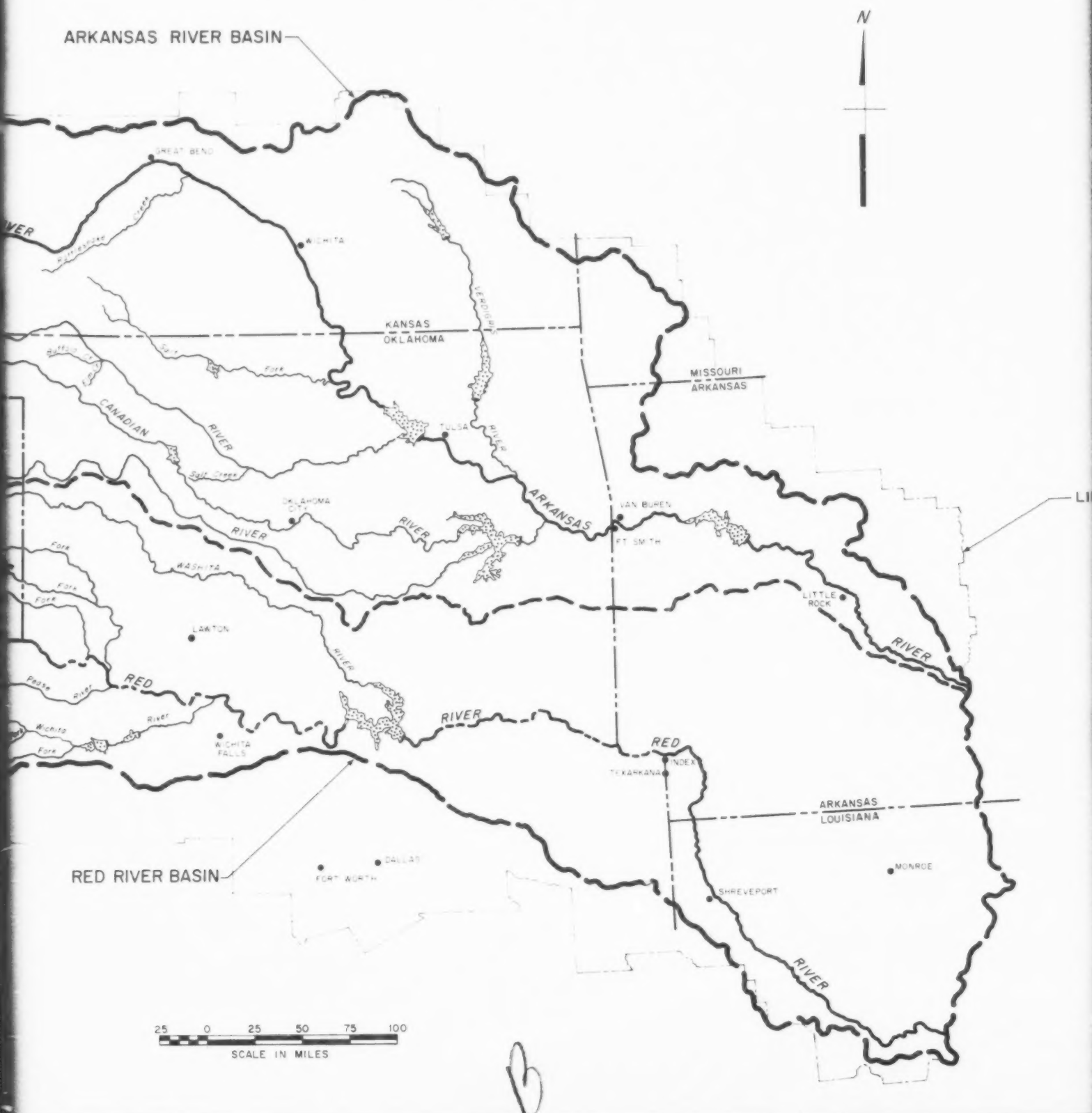
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FT. SMITH
OKLAHOMA CITY
WASHITA
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LAWTON
LITTLE ROCK
RED
RIVER
WICHITA FALLS
TEXARKANA
INDEX
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LOUISIANA
RED RIVER BASIN
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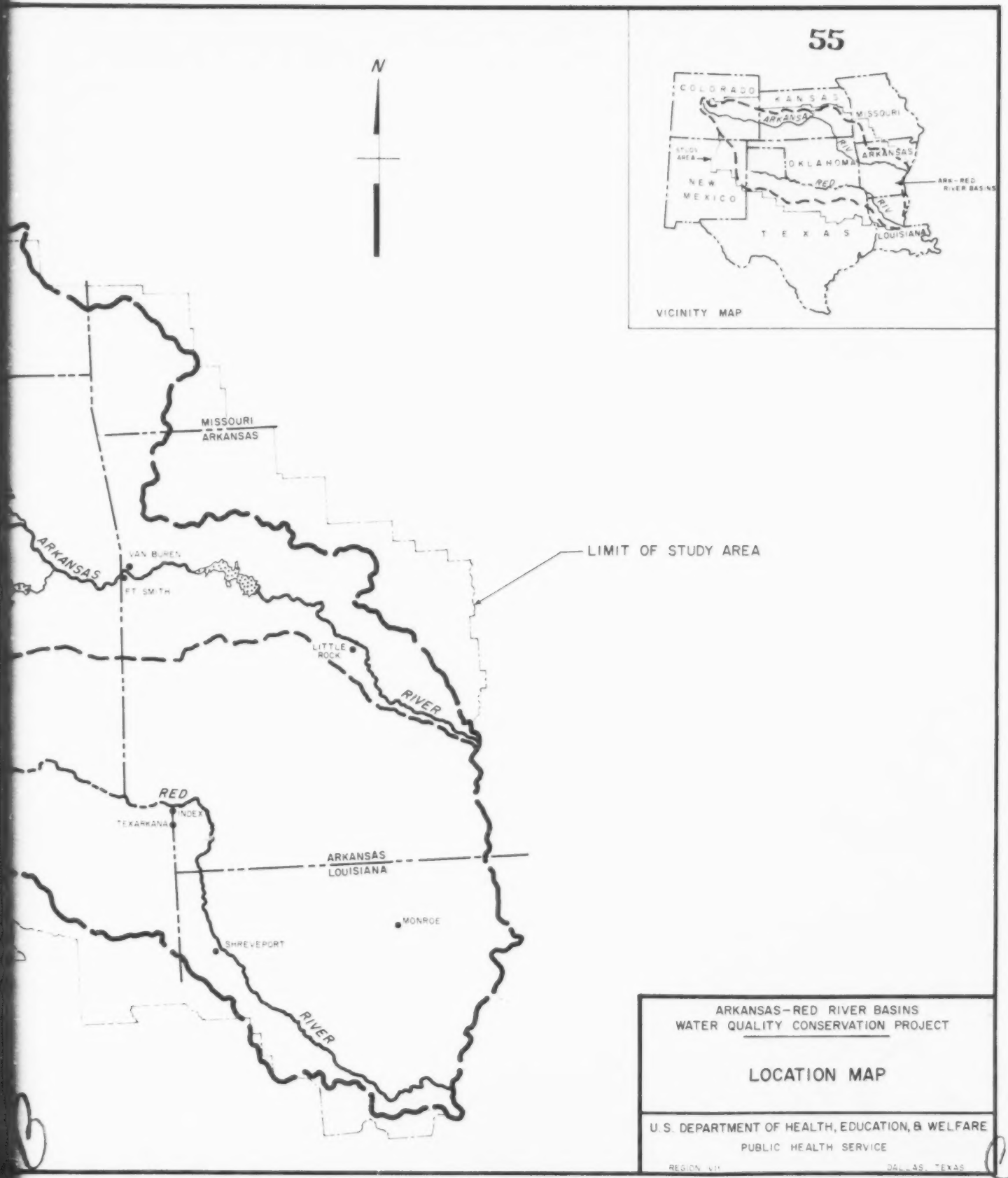

ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

LOCATION MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VI DALLAS, TEXAS

FIGURE IV-1

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